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(54) **MEDICAL MONITORING ANALYSIS AND REPLAY INCLUDING INDICIA RESPONSIVE TO LIGHT ATTENUATED BY BODY TISSUE**

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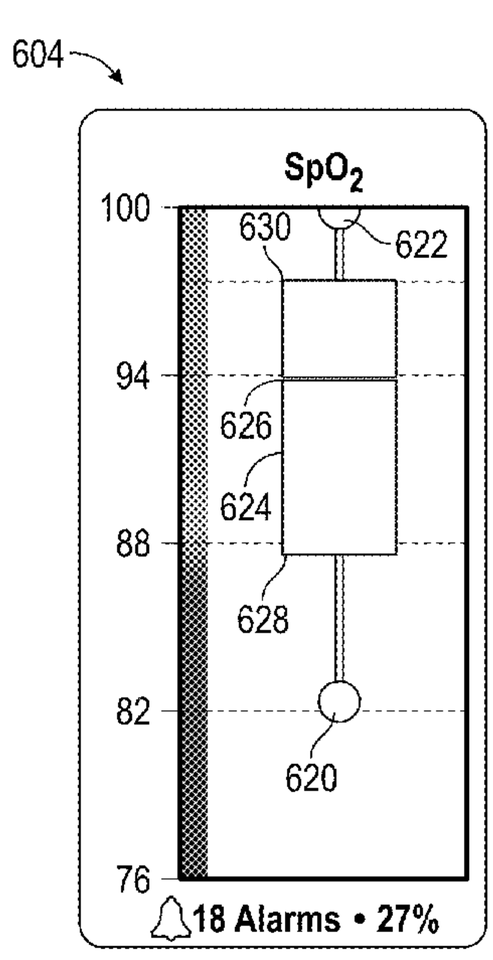
(57) **ABSTRACT**

The present disclosure includes a medical monitoring hub as the center of monitoring for a monitored patient. The hub is configured to receive and process a plurality of physiological parameters associated with the patient. The hub includes advanced analytical presentation views configured to provide timely, clinically-relevant, actionable information to care providers. In certain embodiments, the monitoring hub stores and is able to replay previously presented data reflective of the patient's condition.

18 Claims, 11 Drawing Sheets



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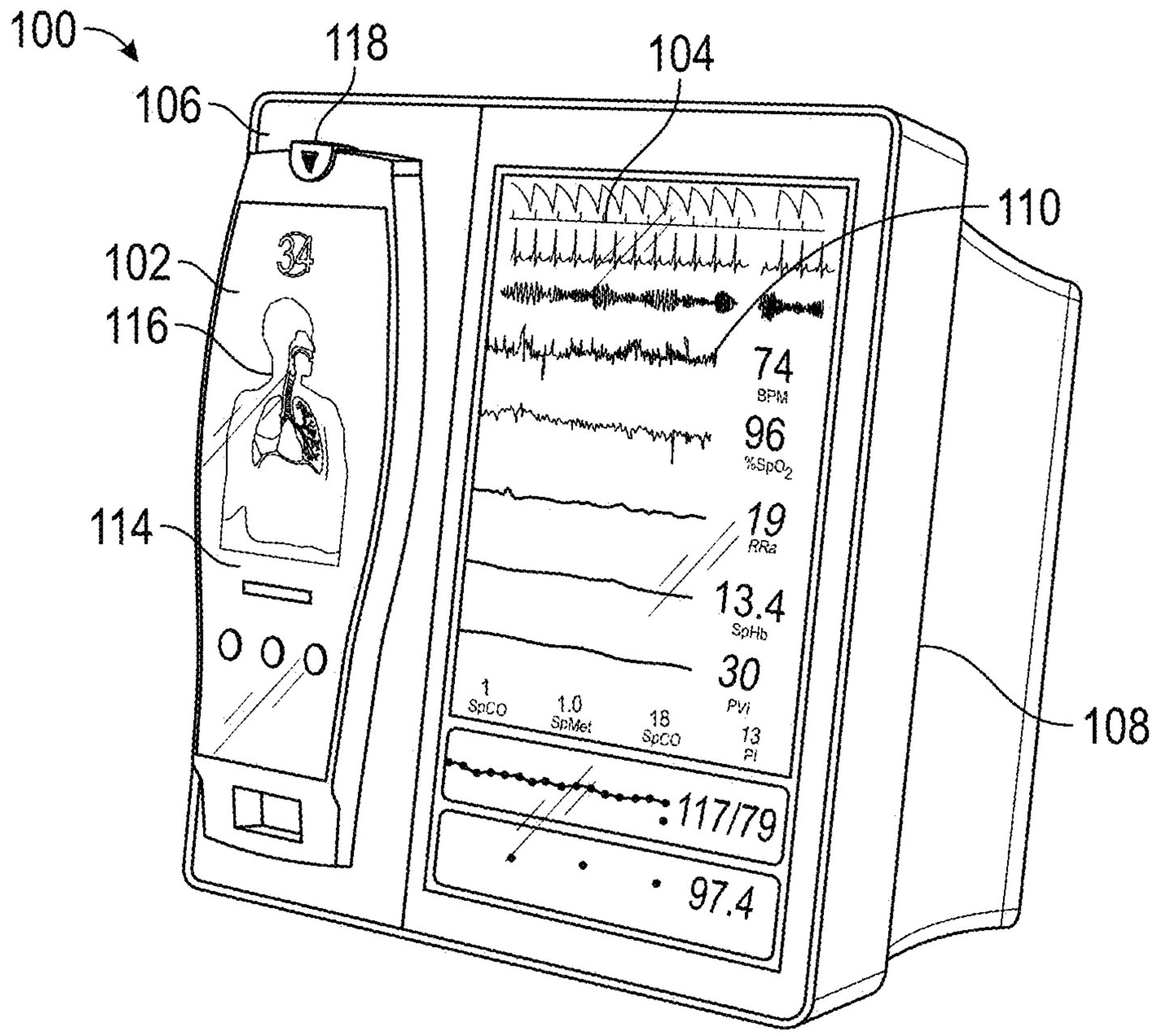
100
118
106
104
110
102
116
114
74
BPM
96
%SpO2
19
RRa
13.4
SpHb
30
PVi
1
SpCO
1.0
SpMet
18
SpCO
13
PI
117/79
97.4
108

FIG. 1A

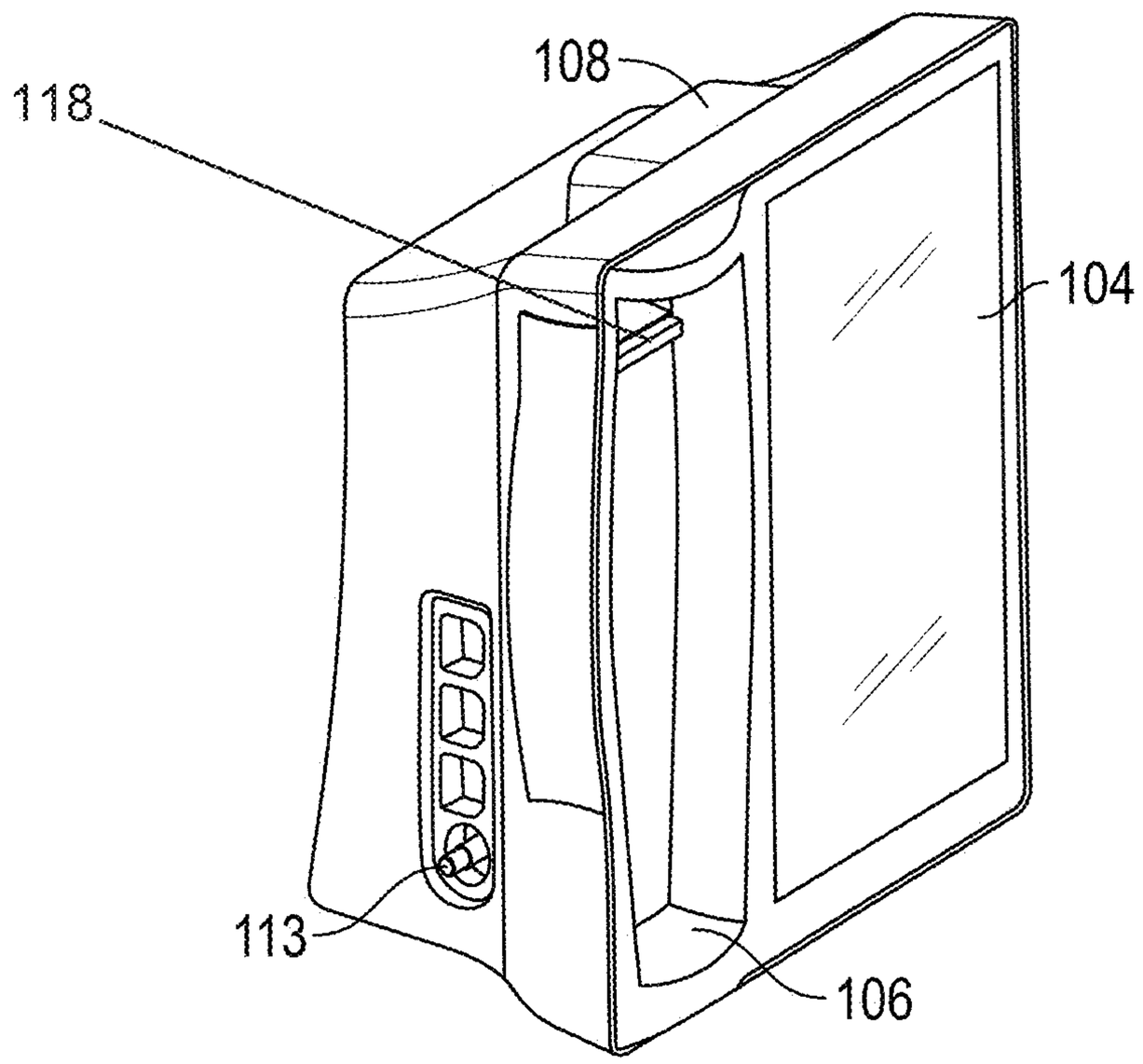
108
118
104
113
106

FIG. 1B

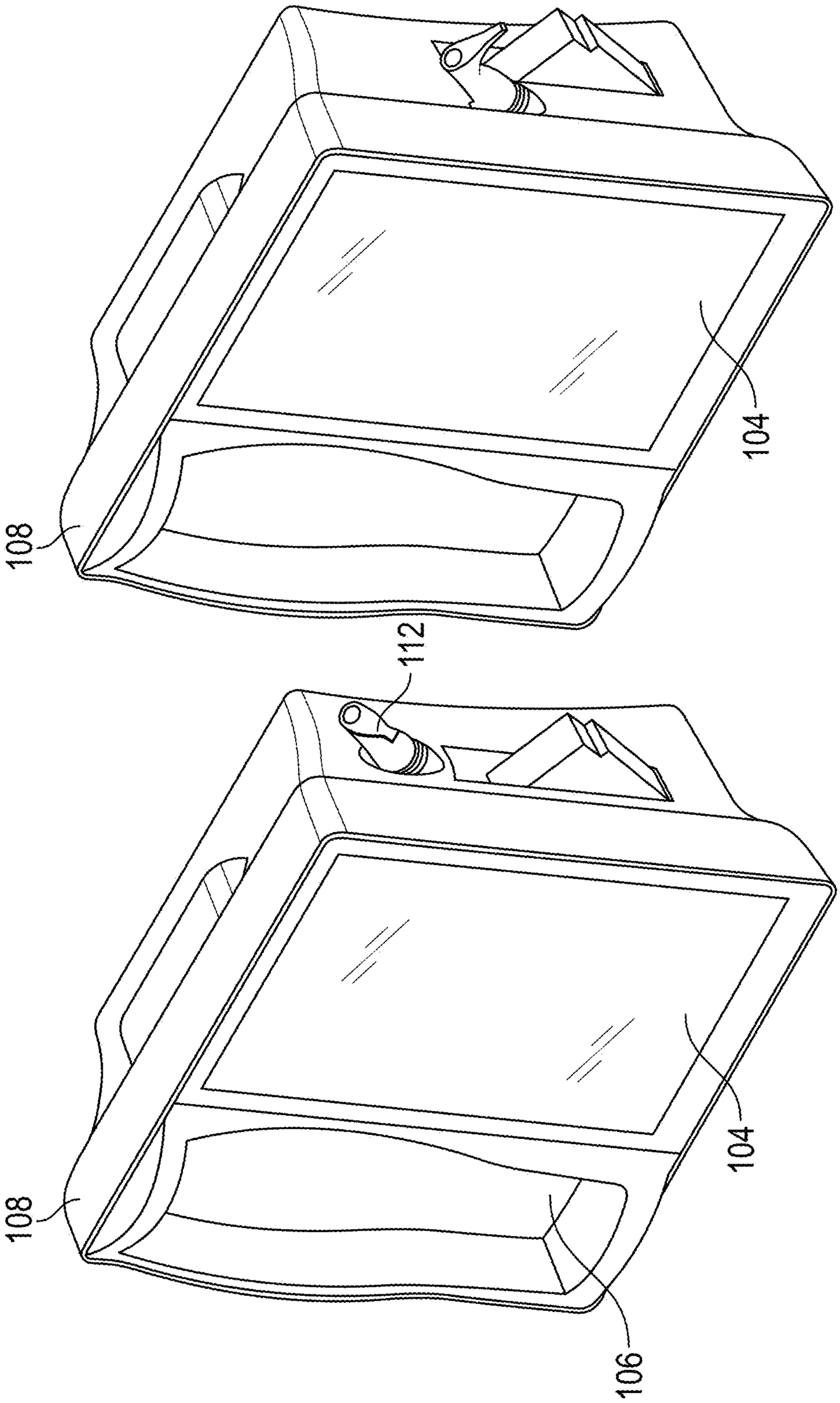

FIG. 1C

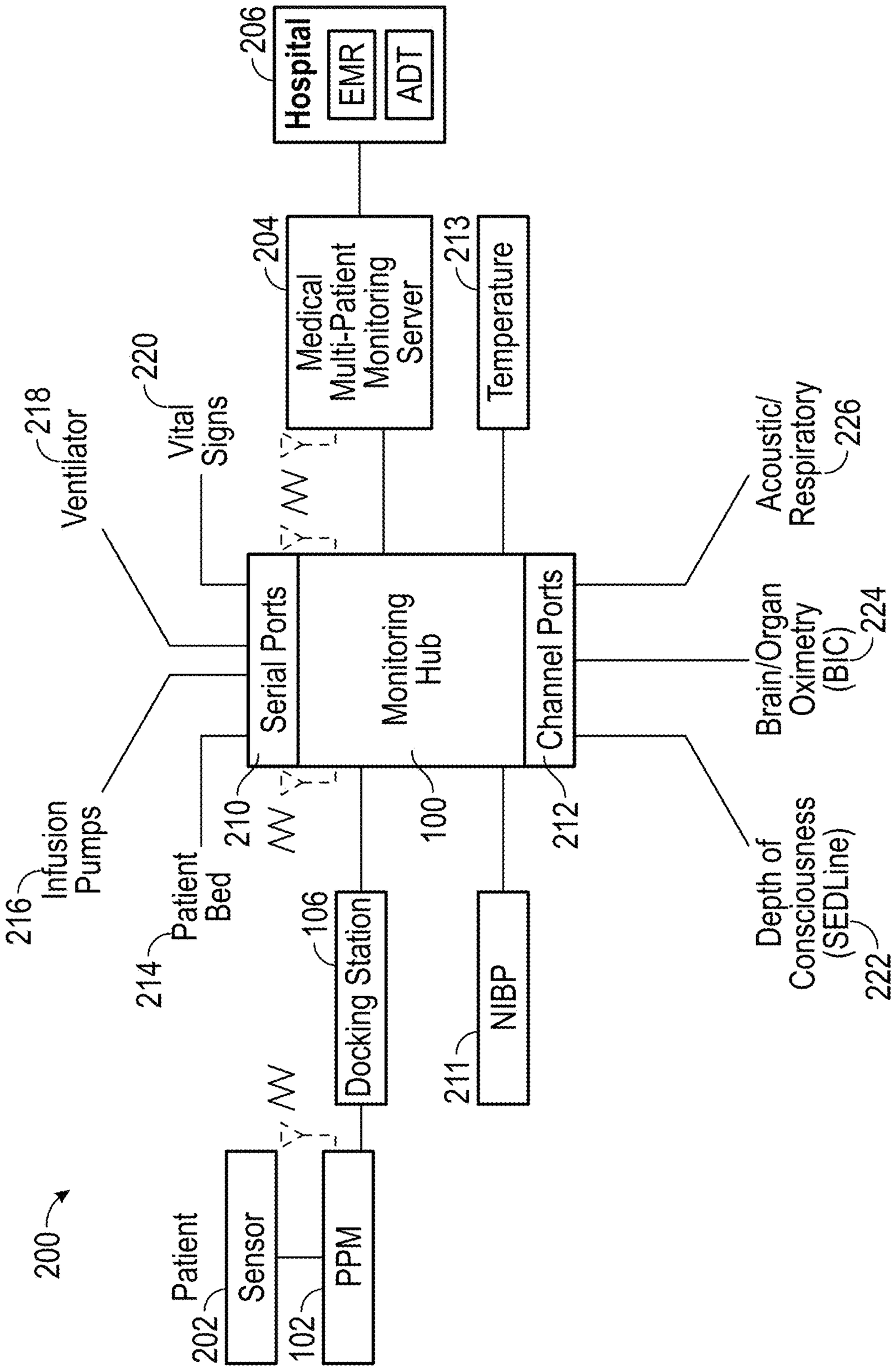
200
Patient
202
Sensor
102
PPM
Docking Station
106
Monitoring Hub
100
Serial Ports
210
Channel Ports
212
Hospital
206
EMR
ADT
Medical Multi-Patient Monitoring Server
204
Temperature
213
NIBP
211
Ventilator
218
Vital Signs
220
Infusion Pumps
216
Patient Bed
214
Acoustic/ Respiratory
226
Brain/Organ Oximetry (BIC)
224
Depth of Consciousness (SEDLine)
222

FIG. 2

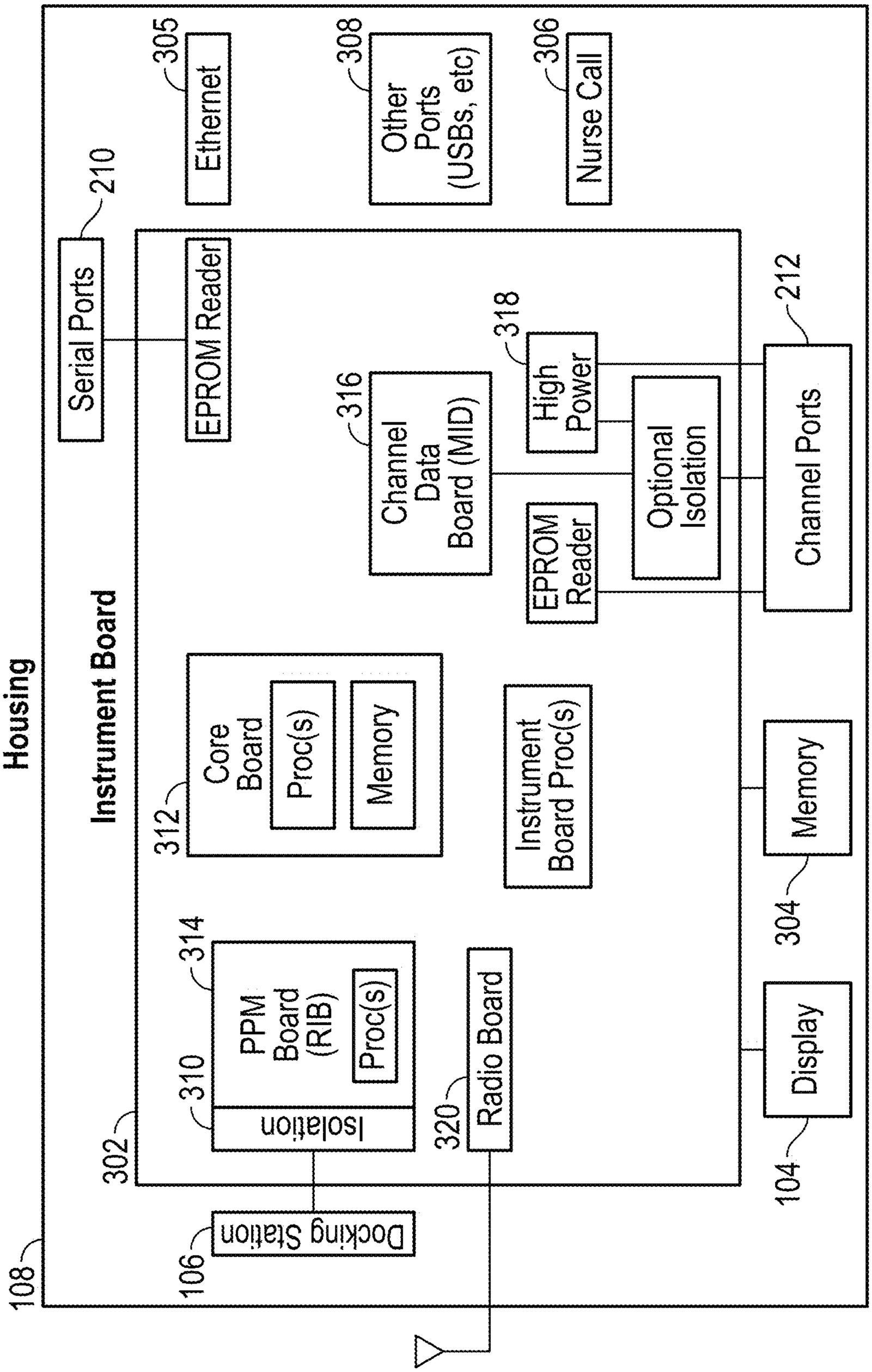
Housing
Instrument Board
Serial Ports
210
EPROM Reader
305
Ethernet
308
Other Ports (USBs, etc)
306
Nurse Call
212
316
Channel Data Board (MID)
318
High Power
Optional Isolation
EPROM Reader
Channel Ports
312
Core Board
Proc(s)
Memory
Instrument Board Proc(s)
304
Memory
314
PPM Board (RIB)
Proc(s)
310
Isolation
320
Radio Board
Display
104
302
Docking Station
106
108

FIG. 3

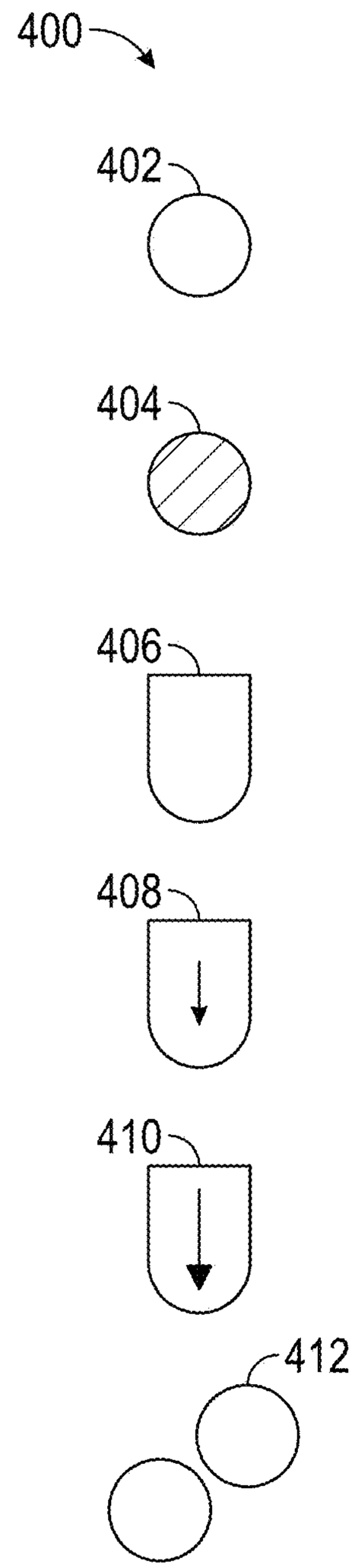

FIG. 4

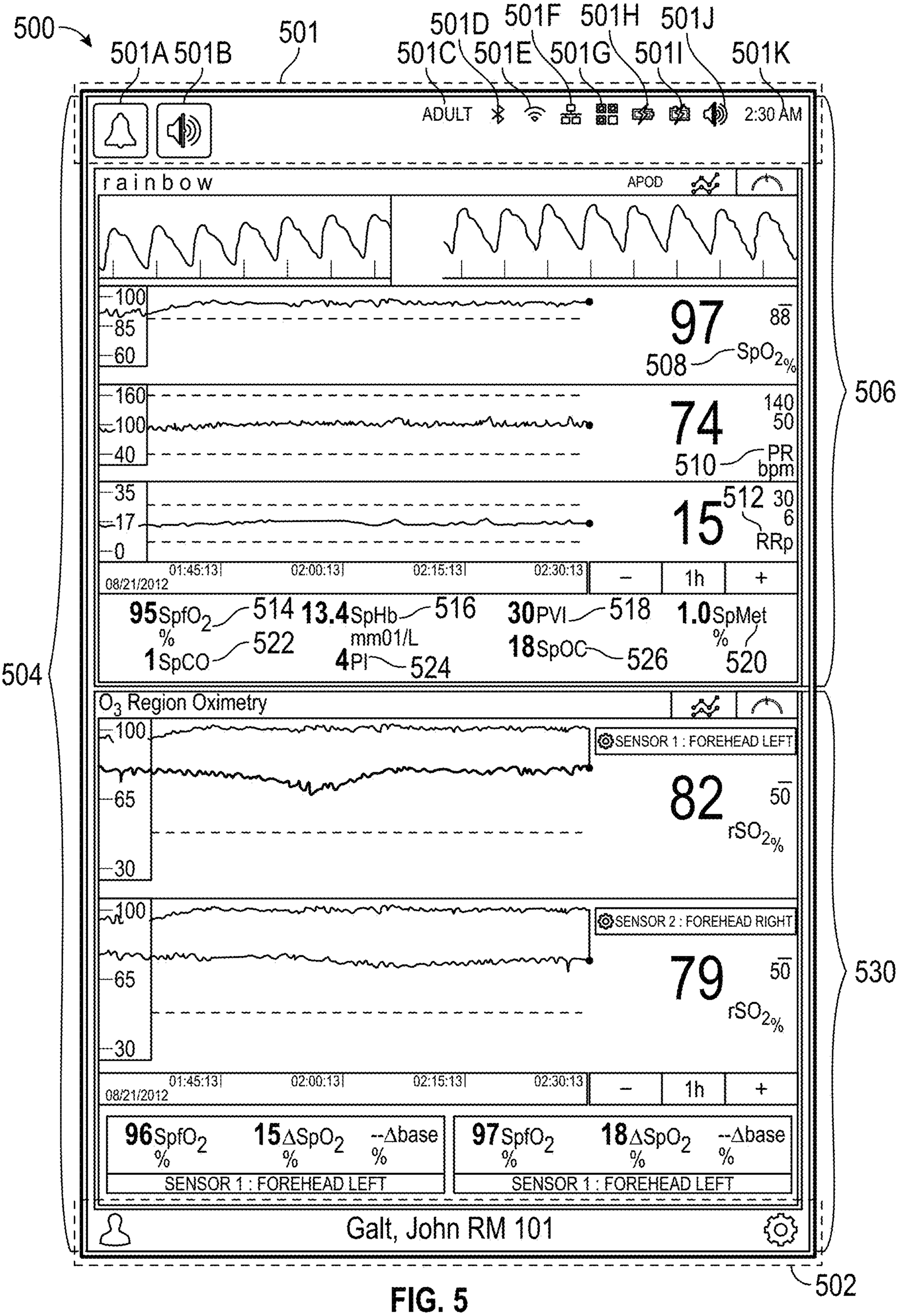
500
501
501A
501B
501C
501D
501E
501F
501G
501H
501I
501J
501K
ADULT
2:30 AM
rainbow
APOD
100
85
60
97
88
SpO2%
508
160
100
40
74
140
50
PR
bpm
510
35
17
0
15
512
30
6
RRp
01:45:13
02:00:13
02:15:13
02:30:13
08/21/2012
–
1h
+
95 SpfO2 %
514
13.4 SpHb mm01/L
516
30 PVI
518
1.0 SpMet %
520
1 SpCO
522
4 PI
524
18 SpOC
526
504
506
O3 Region Oximetry
100
65
30
SENSOR 1 : FOREHEAD LEFT
82
50
rSO2%
SENSOR 2 : FOREHEAD RIGHT
79
96 SpfO2 %
15 ΔSpO2 %
--Δbase %
97 SpfO2 %
18 ΔSpO2 %
--Δbase %
530
Galt, John RM 101
502

FIG. 5

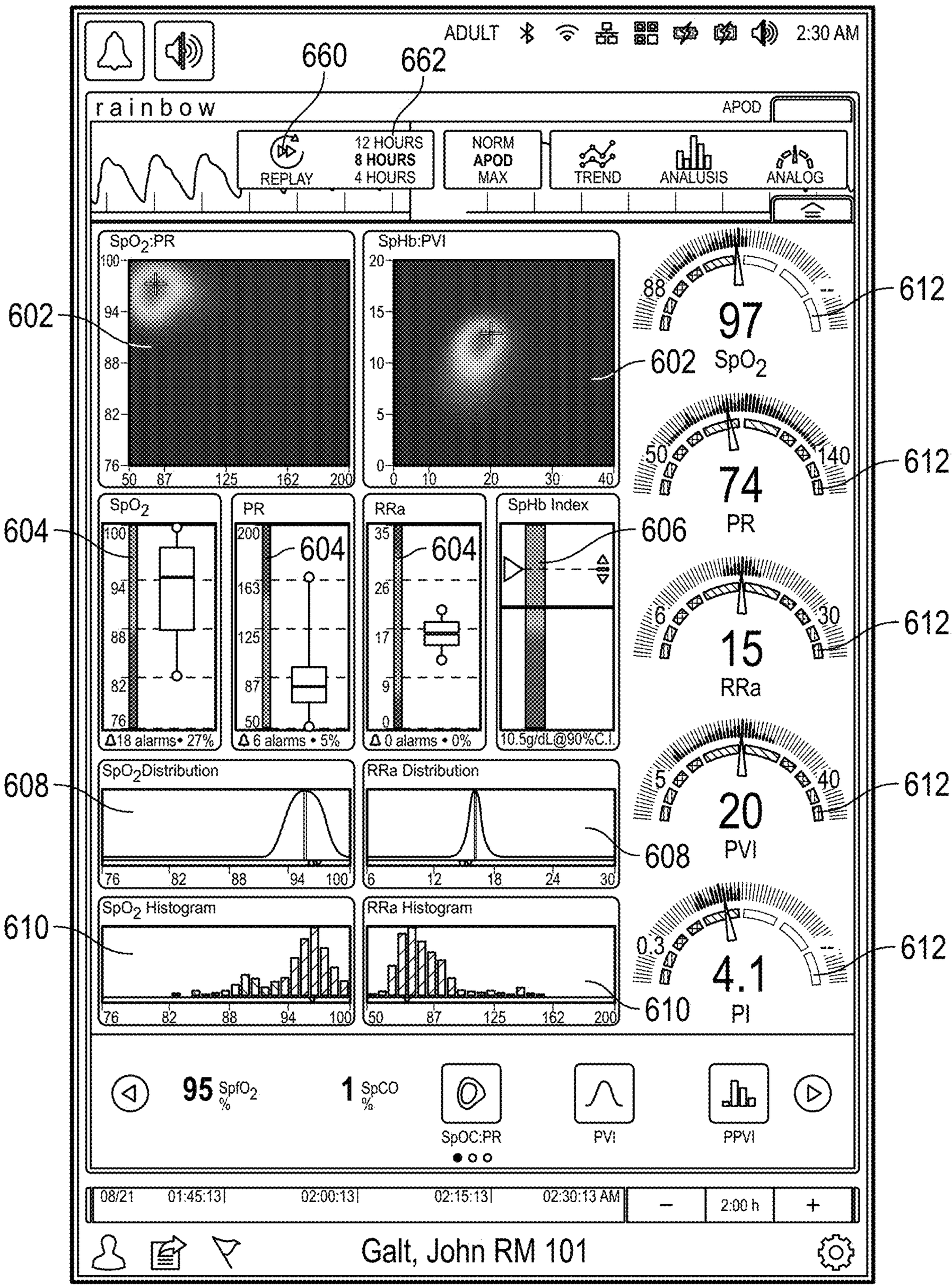
600
ADULT
2:30 AM
660
662
rainbow
APOD
REPLAY
12 HOURS
8 HOURS
4 HOURS
NORM
APOD
MAX
TREND
ANALUSIS
ANALOG
SpO2:PR
SpHb:PVI
602
604
606
608
610
612
SpO2
PR
RRa
SpHb Index
Δ18 alarms• 27%
Δ 6 alarms • 5%
Δ 0 alarms • 0%
10.5g/dL@90%C.I.
SpO2Distribution
RRa Distribution
SpO2 Histogram
RRa Histogram
97 SpO2
74 PR
15 RRa
20 PVI
4.1 PI
95 SpfO2 %
1 SpCO %
SpOC:PR
PVI
PPVI
08/21 01:45:13 02:00:13 02:15:13 02:30:13 AM
2:00 h
Galt, John RM 101

FIG. 6A

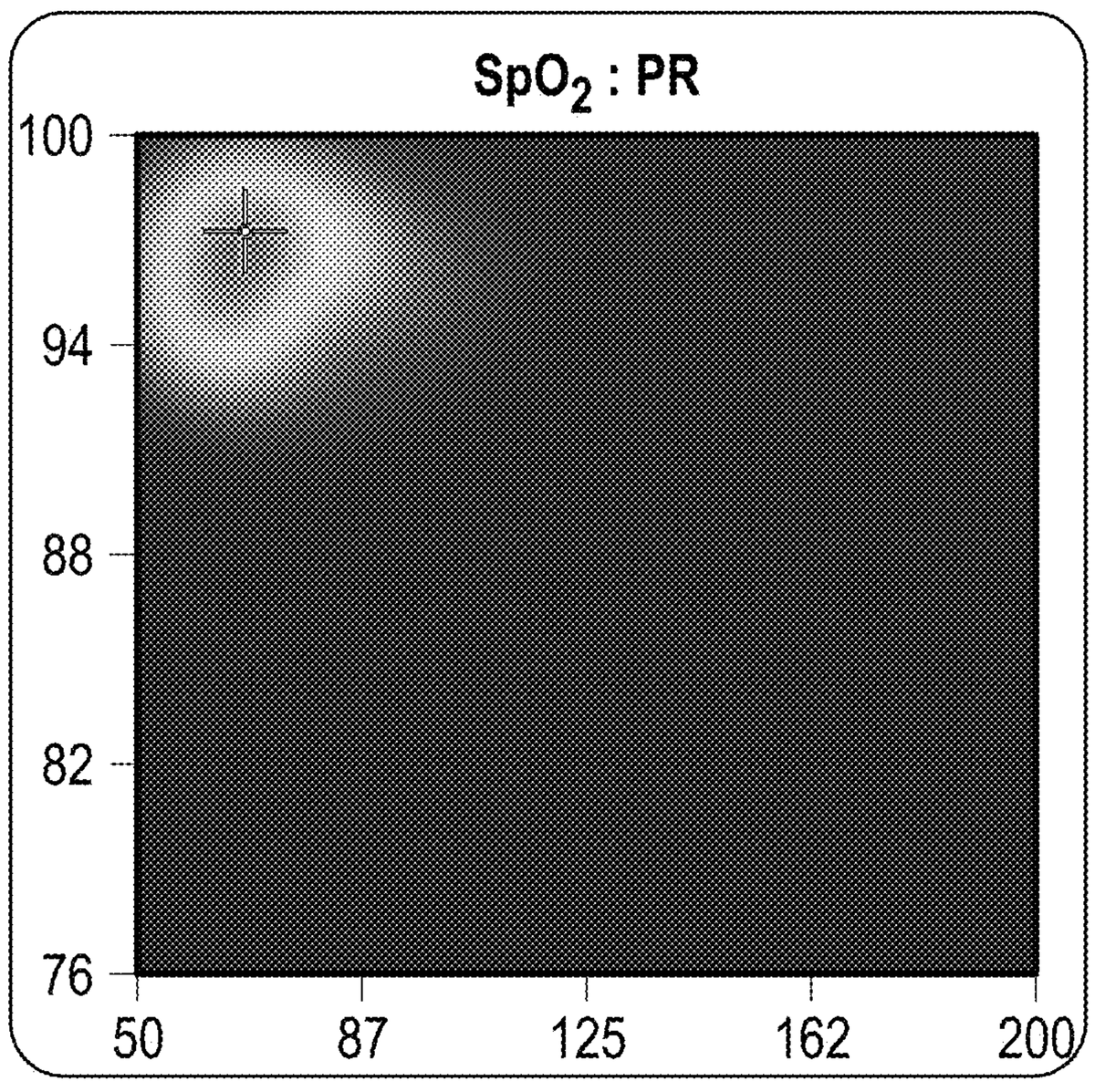

FIG. 6B

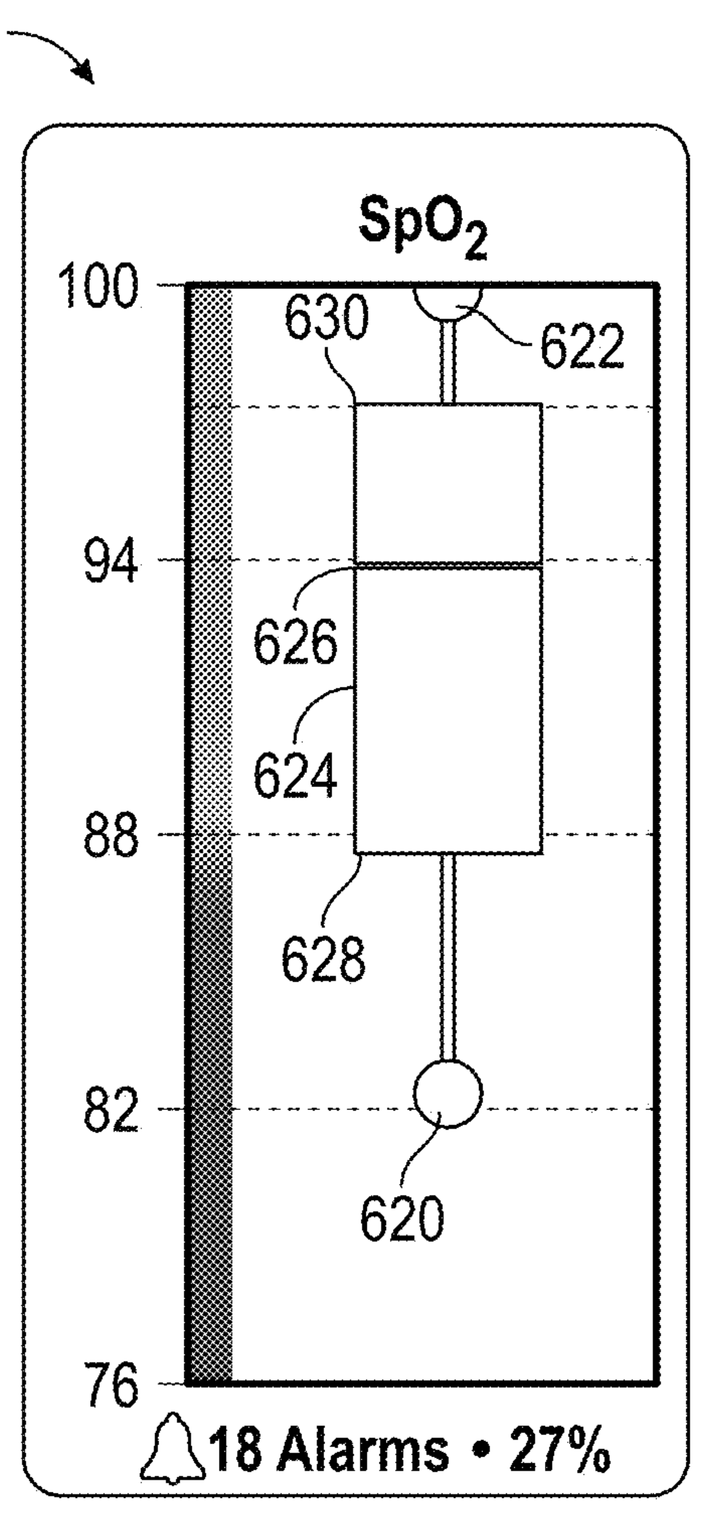

FIG. 6C

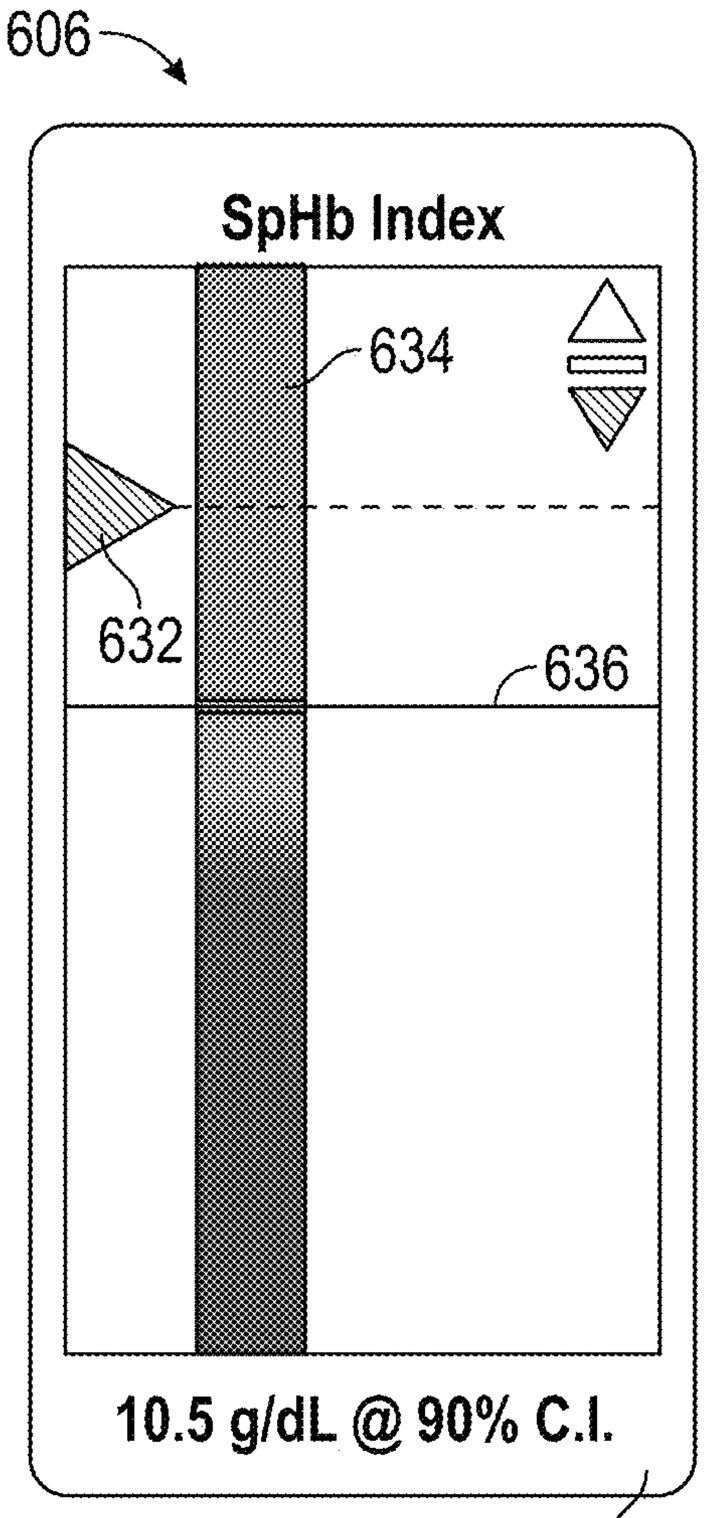

FIG. 6D

FIG. 6E

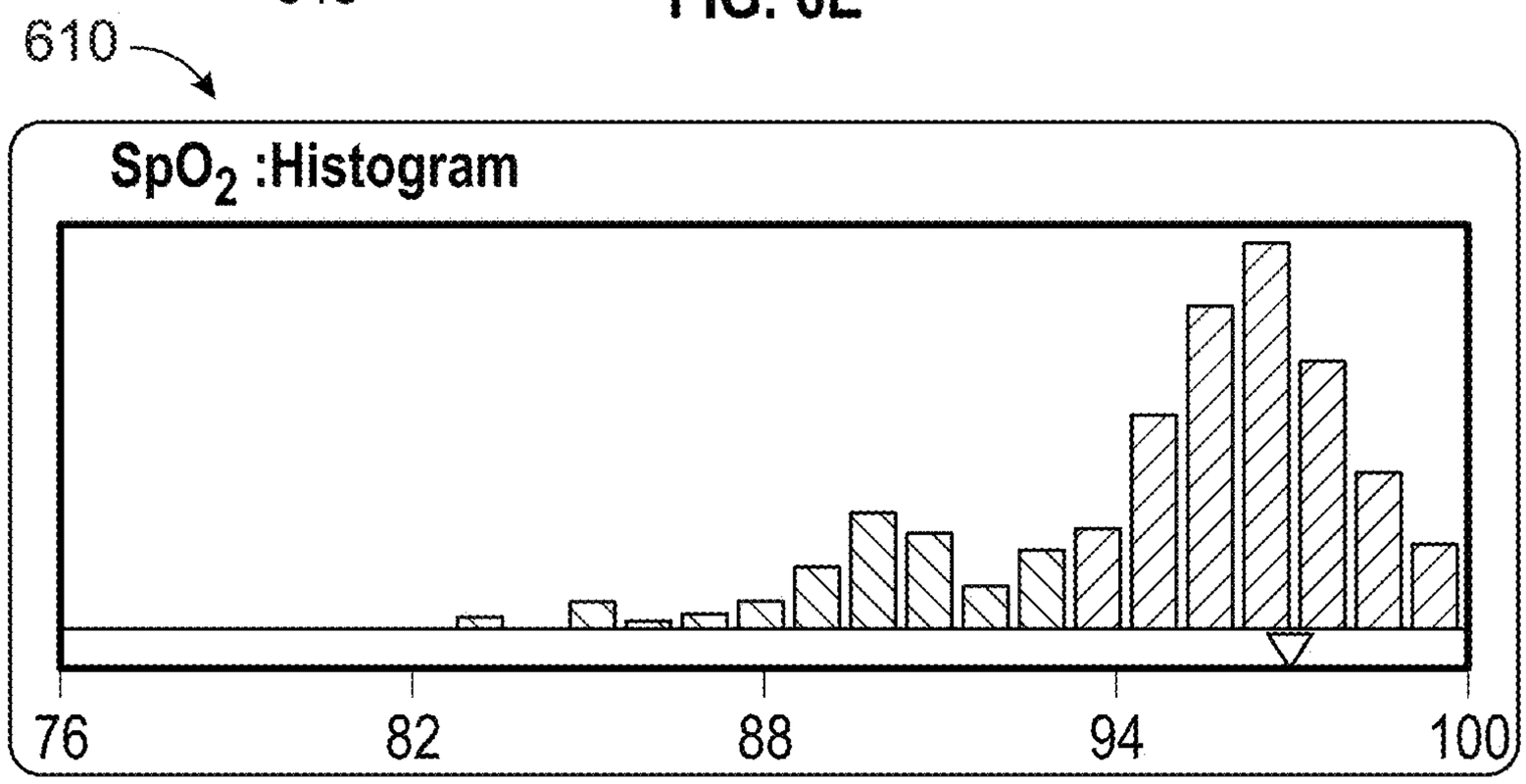

FIG. 6F

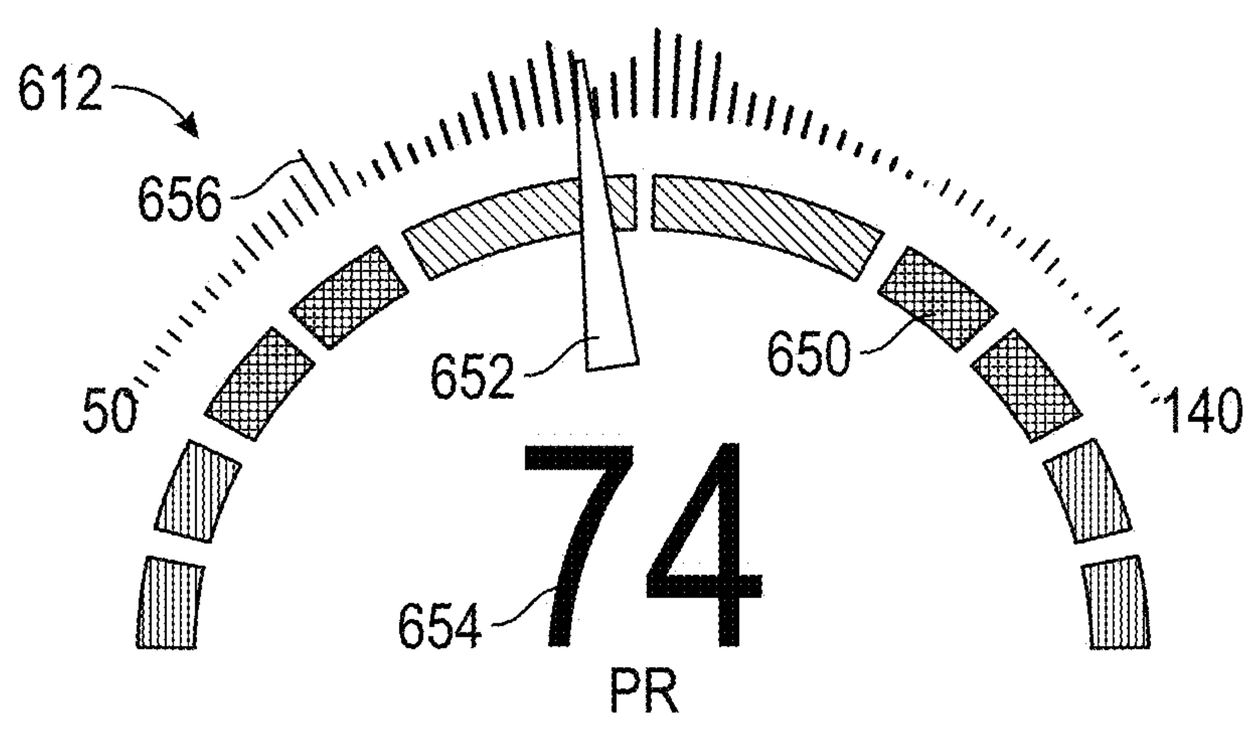

FIG. 6G

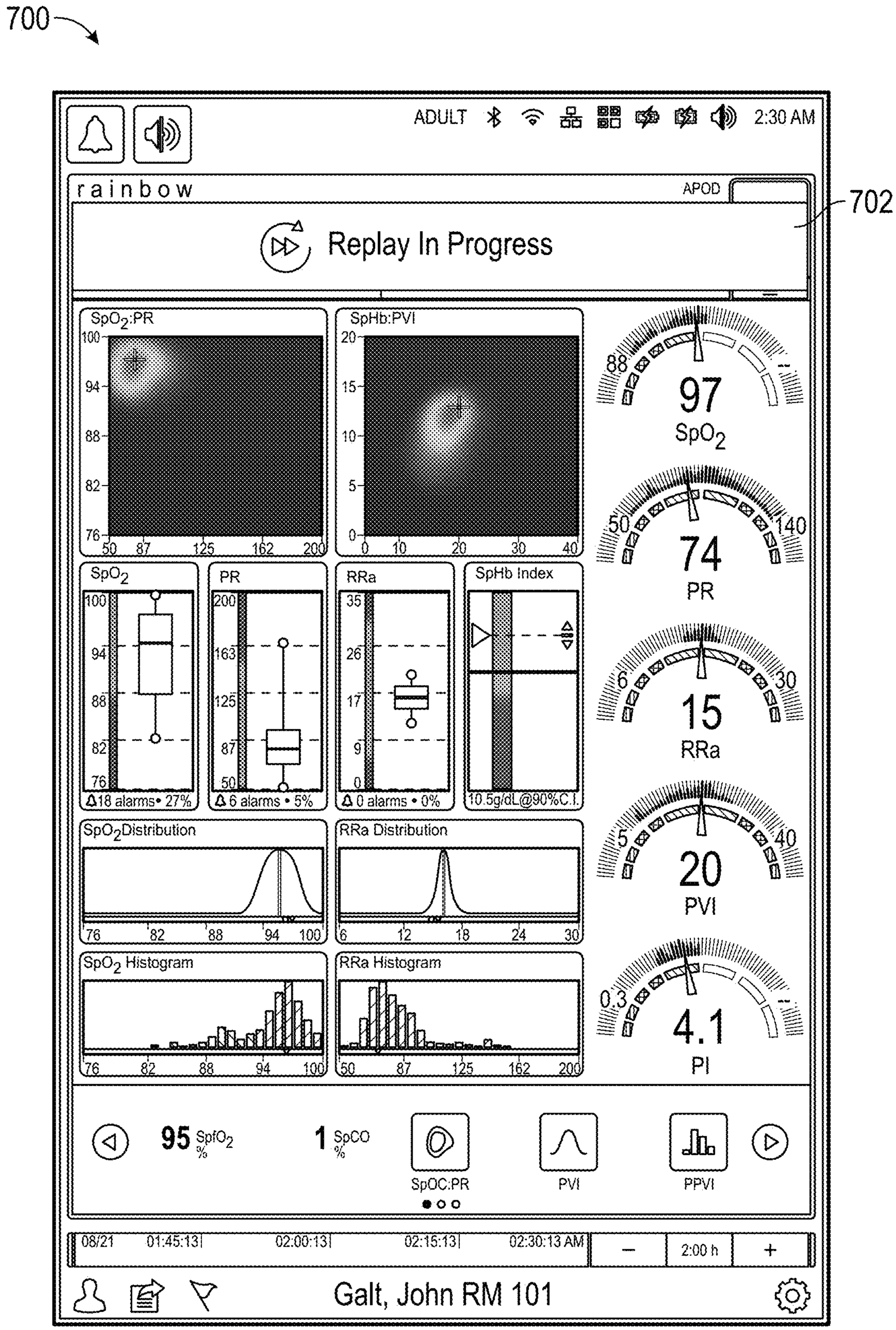
700
ADULT
2:30 AM
rainbow
APOD
702
Replay In Progress
SpO2:PR
SpHb:PVI
SpO2
PR
RRa
SpHb Index
18 alarms • 27%
6 alarms • 5%
0 alarms • 0%
10.5g/dL@90%C.I.
SpO2Distribution
RRa Distribution
SpO2 Histogram
RRa Histogram
97
SpO2
74
PR
15
RRa
20
PVI
4.1
PI
95 SpfO2 %
1 SpCO %
SpOC:PR
PVI
PPVI
08/21 01:45:13 02:00:13 02:15:13 02:30:13 AM
2:00 h
Galt, John RM 101

FIG. 7

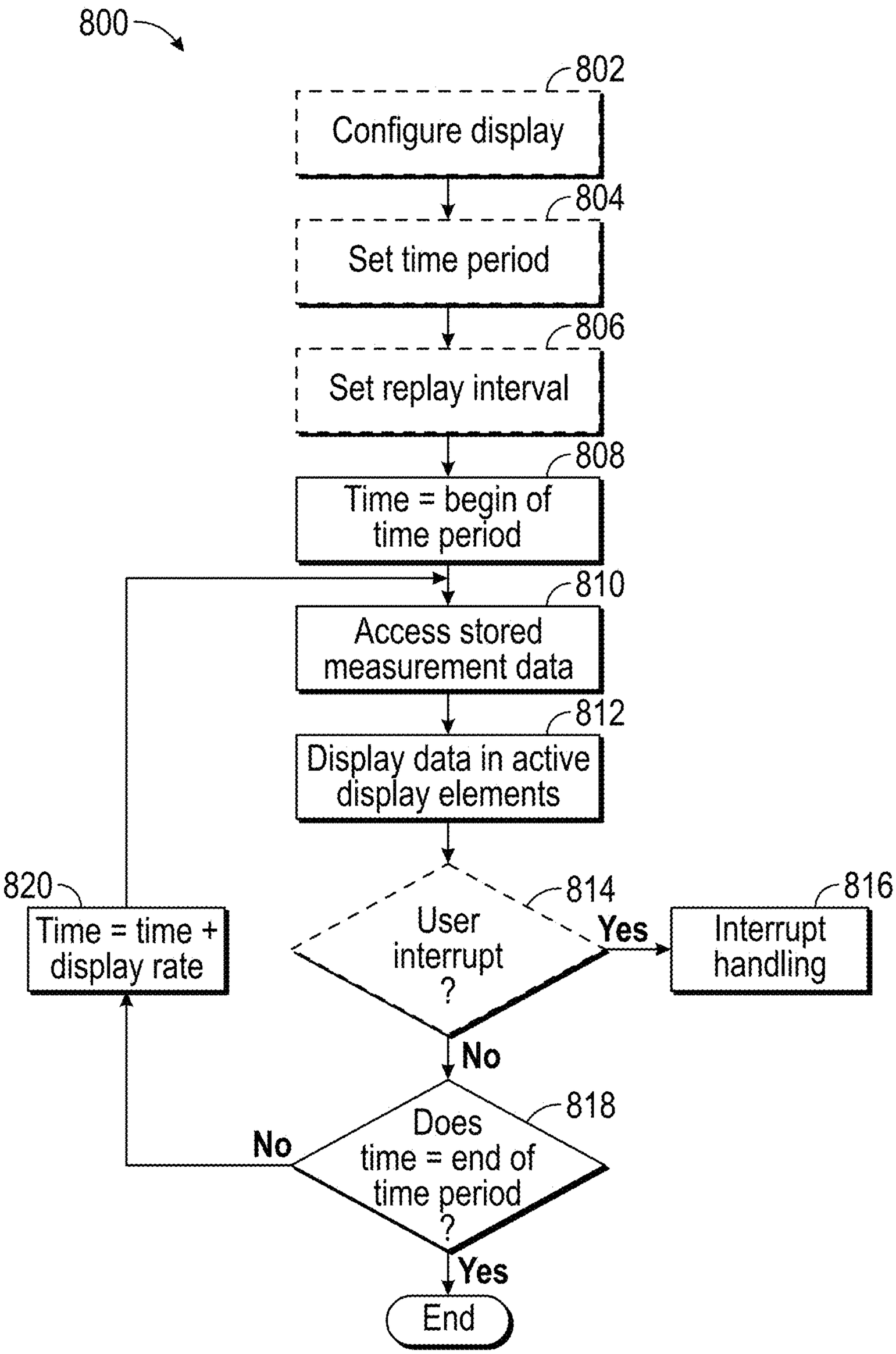
800
802
Configure display
804
Set time period
806
Set replay interval
808
Time = begin of time period
810
Access stored measurement data
812
Display data in active display elements
814
User interrupt ?
Yes
816
Interrupt handling
No
818
Does time = end of time period ?
No
Yes
820
Time = time + display rate
End

FIG. 8

MEDICAL MONITORING ANALYSIS AND REPLAY INCLUDING INDICIA RESPONSIVE TO LIGHT ATTENUATED BY BODY TISSUE

INCORPORATION BY REFERENCE TO ANY PRIORITY APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 15/233,244, filed Aug. 10, 2016, entitled "MEDICAL MONITORING ANALYSIS AND REPLAY INCLUDING INDICIA RESPONSIVE TO LIGHT ATTENUATED BY BODY TISSUE," now U.S. Pat. No. 10,991,135, which claims priority benefit under 35 U.S.C. § 119(e) to U.S. Provisional Application No. 62/203,792, filed Aug. 11, 2015, which is hereby incorporated by reference in its entirety herein. Any and all applications for which a foreign or domestic priority claim is identified in the Application Data Sheet as filed with the present application are hereby incorporated by reference under 37 CFR 1.57.

FIELD

The present disclosure relates generally to a patient monitor and medical data communication hub and specifically to a patient monitor including display elements for presenting measurement information, often over a time period, to a caregiver.

BACKGROUND

Today's patient monitoring environments are crowded with sophisticated and often electronic medical devices servicing a wide variety of monitoring and treatment endeavors for a given patient. Generally, many if not all of the devices are from differing manufactures, and many may be portable devices. The devices may not communicate with one another and each may include its own control, display, alarms, configurations and the like. Complicating matters, caregivers often desire to associate all types of measurement and data from these devices with a specific patient. Patient information entry often occurs at each device. Sometimes, the disparity in devices leads to a need to simply print and store paper from each device in a patient's file for caregiver review.

Thus, while the electronic collection of physiological data associated with the patient's condition has increased, the ability to synthesize the collected patient data into timely, clinically-relevant, actionable information remains a challenge.

SUMMARY

Based on at least the foregoing, a solution is needed that coordinates the various medical devices treating or monitoring a patient and the measurement data being generated by such devices. Embodiments of such a solution may include a medical hub that presents, via graphical display, a variety of analytical presentation views that deliver to the caregiver easily-seen, intuitive, visual indications of the status and condition of the patient being monitored. In an embodiment, the analytical graphical views may advantageously be replayed for analysis of critical events in the patient's care, or to simply review the patient's physiological activity over a period of time. In an embodiment, the replays of several physiological parameters may be played synchronously, providing a broad perspective of the patient's historical activity.

According to an embodiment of the present disclosure, a medical monitoring hub is configured to monitor physiological parameters of a patient. The hub includes a first communication port configured to receive a first signal indicative a first physiological parameter associated with the patient. The monitor also includes a display configured to present analytical presentation views to the user. The monitor includes at least one processor configured to process the received first signal and to cause a first view to be presented on at least a portion of the display. The first view is adapted to present first data indicative of the first physiological parameter collected over a first period of time. The hub includes a storage device configured to store the presented first data, and the processor is further configured to replay the stored first data on the display.

In certain embodiments of the present disclosure, various analytical presentation views are disclosed to help clinicians easily and intuitively interpret the patient data that is received by the monitoring hub. Heat maps are disclosed which provide a two-dimensional graphical representation of a relationship between two measured physiological parameters over a specified period of time. Advantageously, heat maps use color to identify areas in the graph where the data is concentrated. For example, areas where the data is highly concentrated can be presented in a first color (e.g., red), while areas in which the data is less highly concentrated can be presented in a second color (e.g., blue).

Also disclosed are box-and-whisker plots which visually present the range of physiological parameter measurements received over a specified or pre-determined period of time. Additionally, the boundaries of the quartiles in which the data lies are presented by the box-and-whisker plots. Advantageously, the box-and-whisker plot readily presents to the user the degree of spread, or dispersion of the measured data, as well as the skewness in the data, including outlier measurements.

Index box views are disclosed as well. An index box view presents a current measured state of a physiological parameter relative to ranges identified as, for example, acceptable, cautionary, and emergent, using colors and other visual cues to readily indicate the measured state of the patient.

The present disclosure also describes distribution analytical presentation views which present a statistical distribution (e.g., a Gaussian distribution) of physiological parameter measurements over a specified or pre-defined period of time. Similarly, the present disclosure describes histogram analytical presentation views which provide yet another graphical representation of a measured physiological parameter data. A histogram represents an estimate of the statistical (or probability) distribution of a continuous variable, such as a continuously measured physiological parameter. Thus, rather than providing a statistical distribution (i.e., a probabilistic model) that best fits or corresponds to the measured data, the histogram reflects the actual measured data collected.

The present disclosure also includes gauge-histogram analytical presentation views, which provide a combination of analog, digital, and histogram display indicia. Advantageously, the gauge-histogram analytical presentation view provides to the clinician a substantial amount of information related to the measured physiological parameter in an intuitive and visually accessible format.

In use, the clinician is provided a great deal of flexibility in arranging and configuring the disclosed analytical presentation views of the present disclosure. Thus, the clinician is provided a monitoring environment that can be customized to the clinician's and/or patient's specific needs.

For purposes of summarizing the disclosure, certain aspects, advantages and novel features are discussed herein. It is to be understood that not necessarily all such aspects, advantages or features will be embodied in any particular embodiment of the invention, and an artisan would recognize from the disclosure herein a myriad of combinations of such aspects, advantages or features.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments will be described hereinafter with reference to the accompanying drawings. The drawings and the associated descriptions are provided to illustrate embodiments of the present disclosure and do not limit the scope of the claims. In the drawings, similar elements have similar reference numerals.

FIGS. **1**A-**1**C illustrate perspective views of an exemplary medical monitoring hub according to an embodiment of the disclosure. For example, FIG. **1**A illustrates the hub with an exemplary docked portable patient monitor; FIG. **1**B illustrates the hub with a set of medical ports and a noninvasive blood pressure input; and FIG. **1**C illustrates the hub with various exemplary temperature sensors attached thereto, all according to various embodiments of the disclosure.

FIG. **2** illustrates a simplified block diagram of an exemplary monitoring environment including the hub of FIG. **1**, according to an embodiment of the disclosure.

FIG. **3** illustrates a simplified exemplary hardware block diagram of the hub of FIG. **1**, according to an embodiment of the disclosure.

FIG. **4** is a finger control gesture legend for a touchscreen interface according to an embodiment of the disclosure.

FIG. **5** is an illustration of a display view according to an embodiment of the disclosure.

FIG. **6**A illustrates an exemplary display screen showing various analytical presentation views for presenting received and processed data according to an embodiment of the disclosure.

FIG. **6**B illustrates a heat map analytical presentation view according to an embodiment of the disclosure.

FIG. **6**C illustrates a box-and-whisker analytical presentation view according to an embodiment of the disclosure.

FIG. **6**D illustrates an index analytical presentation view according to an embodiment of the disclosure.

FIG. **6**E illustrates a distribution analytical presentation view according to an embodiment of the disclosure.

FIG. **6**F illustrates a histogram analytical presentation view according to an embodiment of the disclosure.

FIG. **6**G illustrates a gauge-histogram analytical presentation view according to an embodiment of the disclosure.

FIG. **7** illustrates an exemplary display screen showing a replay feature according to an embodiment of the disclosure.

FIG. **8** is a flowchart illustrating a replay process according to an embodiment of the disclosure.

While the foregoing "Brief Description of the Drawings" references generally various embodiments of the disclosure, an artisan will recognize from the disclosure herein that such embodiments are not mutually exclusive. Rather, the artisan would recognize a myriad of combinations of some or all of such embodiments.

DETAILED DESCRIPTION

The present disclosure relates to a medical monitoring hub configured to be the center of monitoring activity for a given patient. In an embodiment, the hub comprises a large easily readable display, such as an about ten (10) inch display dominating the majority of real estate on a front face of the hub. The display could be much larger or much smaller depending upon design constraints. However, for portability and current design goals, the preferred display is roughly sized proportional to the vertical footprint of one of a dockable portable patient monitor. Other considerations are recognizable from the disclosure herein by those in the art.

Configurable Replay Display

In an embodiment, the display is configurable by dragging and dropping gestures to populate the display with elements a caregiver prefers to view for a particular user. The elements may include some or all of a heat map, a box-and-whisker plot, a distribution plot, a histogram, an analog gage, and an analog gage combined with a histogram. Once configured, the hub processor may allow for the replay of selected measurement data, data responsive to the measurement data, or combinations of measurement data over a selected or default time period at a selected or default display rate. Advantageously, such configuration and replay provide a powerful tool for a caregiver to review the patient's condition over virtually any period of time desired.

Monitoring Hub

The display provides measurement data for a wide variety of monitored parameters for the patient under observation in numerical or graphic form, and in various embodiments, is automatically configured based on the type of data and information being received at the hub. In an embodiment, the hub is moveable, portable, and mountable so that it can be positioned to convenient areas within a caregiver environment. For example, the hub is collected within a singular housing.

In an embodiment, the hub may advantageously receive data from a portable patient monitor while docked or undocked from the hub. Typical portable patient monitors, such as oximeters or co-oximeters can provide measurement data for a large number of physiological parameters derived from signals output from optical and/or acoustic sensors, electrodes, or the like. The physiological parameters include, but not limited to oxygen saturation, carboxy hemoglobin, methemoglobin, total hemoglobin, glucose, pH, bilirubin, fractional saturation, pulse rate, respiration rate, components of a respiration cycle, indications of perfusion including perfusion index, signal quality and/or confidences, plethysmograph data, indications of wellness or wellness indexes or other combinations of measurement data, audio information responsive to respiration, ailment identification or diagnosis, blood pressure, patient and/or measurement site temperature, depth of sedation, organ or brain oxygenation, hydration, measurements responsive to metabolism, combinations of the same or the like, to name a few. In other embodiments, the hub may output data sufficient to accomplish closed-loop drug administration in combination with infusion pumps or the like.

In an embodiment, the hub communicates with other devices in a monitoring environment that are interacting with the patient in a number of ways. For example, the hub advantageously receives serial data from other devices without necessitating their reprogramming or that of the hub. Such other devices include pumps, ventilators, all manner of monitors monitoring any combination of the foregoing parameters, ECG/EEG/EKG devices, electronic patient beds, and the like. Moreover, the hub advantageously receives channel data from other medical devices without necessitating their reprogramming or that of the hub. When a device communicates through channel data, the hub may advantageously alter the large display to include measure-

ment information from that device. Additionally, the hub accesses nurse call systems to ensure that nurse call situations from the device are passed to the appropriate nurse call system.

The hub also communicates with hospital systems to advantageously associate incoming patient measurement and treatment data with the patient being monitored. For example, the hub may communicate wirelessly or otherwise to a multi-patient monitoring system, such as a server or collection of servers, which in turn many communicate with a caregiver's data management systems, such as, for example, an Admit, Discharge, Transfer ("ADT") system and/or an Electronic Medical Records ("EMR") system. The hub advantageously associates the data flowing through it with the patient being monitored thereby providing the electronic measurement and treatment information to be passed to the caregiver's data management systems without the caregiver associating each device in the environment with the patient.

In an embodiment, the hub advantageously includes a reconfigurable and removable docking station. The docking station may dock additional layered docking stations to adapt to different patient monitoring devices. Additionally, the docking station itself is modularized so that it may be removed if the primary dockable portable patient monitor changes its form factor. Thus, the hub is flexible in how its docking station is configured.

In an embodiment, the hub includes a large memory for storing some or all of the data it receives, processes, and/or associates with the patient, and/or communications it has with other devices and systems. Some or all of the memory may advantageously comprise removable SD memory.

The hub communicates with other devices through at least (1) the docking station to acquire data from a portable monitor, (2) innovative universal medical connectors to acquire channel data, (3) serial data connectors, such as RJ ports to acquire output data, (4) Ethernet, USB, and nurse call ports, (5) Wireless devices to acquire data from a portable monitor, (6) other wired or wireless communication mechanisms known to an artisan. The universal medical connectors advantageously provide optional electrically isolated power and communications, are designed to be smaller in cross section than isolation requirements. The connectors and the hub communicate to advantageously translate or configure data from other devices to be usable and displayable for the hub. In an embodiment, a software developers kit ("SDK") is provided to a device manufacturer to establish or define the behavior and meaning of the data output from their device. When the output is defined, the definition is programmed into a memory residing in the cable side of the universal medical connector and supplied as an original equipment manufacturer ("OEM") to the device provider. When the cable is connected between the device and the hub, the hub understands the data and can use it for display and processing purposes without necessitating software upgrades to the device or the hub. In an embodiment, the hub can negotiate the schema and even add additional compression and/or encryption. Through the use of the universal medical connectors, the hub organizes the measurement and treatment data into a single display and alarm system effectively and efficiently bringing order to the monitoring environment.

As the hub receives and tracks data from other devices according to a channel paradigm, the hub may advantageously provide processing to create virtual channels of patient measurement or treatment data. In an embodiment, a virtual channel may comprise a non-measured parameter that is, for example, the result of processing data from various measured or other parameters. An example of such a parameter includes a wellness indicator derived from various measured parameters that give an overall indication of the wellbeing of the monitored patient. An example of a wellness parameter is disclosed in U.S. patent application Ser. Nos. 13/269,296, 13/371,767 and 12/904,925, by the assignee of the present disclosure and incorporated by reference herein. By organizing data into channels and virtual channels, the hub may advantageously time-wise synchronize incoming data and virtual channel data.

The hub also receives serial data through serial communication ports, such as RJ connectors. The serial data is associated with the monitored patient and passed on to the multi-patient server systems and/or caregiver backend systems discussed above. Through receiving the serial data, the caregiver advantageously associates devices in the caregiver environment, often from varied manufactures, with a particular patient, avoiding a need to have each individual device associated with the patient and possible communicating with hospital systems. Such association is vital as it reduces caregiver time spent entering biographic and demographic information into each device about the patient. Moreover, in an embodiment, through the SDK the device manufacturer may advantageously provide information associated with any measurement delay of their device, thereby further allowing the hub to advantageously time-wise synchronize serial incoming data and other data associated with the patient.

In an embodiment, when a portable patient monitor is docked, and it includes its own display, the hub effectively increases its display real estate. For example, in an embodiment, the portable patient monitor may simply continue to display its measurement and/or treatment data, which may be now duplicated on the hub display, or the docked display, may alter its display to provide additional information. In an embodiment, the docked display, when docked, presents anatomical graphical data of, for example, the heart, lungs, organs, the brain, or other body parts being measured and/or treated. The graphical data may advantageously animate similar to and in concert with the measurement data. For example, lungs may inflate in approximate correlation to the measured respiration rate and/or the determined inspiration/expiration portions of a respiration cycle, the heart may beat according to the pulse rate, may beat generally along understood actual heart contraction patterns, the brain may change color or activity based on varying depths of sedation, or the like. In an embodiment, when the measured parameters indicate a need to alert a caregiver, a changing severity in color may be associated with one or more displayed graphics, such as the heart, lungs, brain, organs, circulatory system or portions thereof, respiratory system or portions thereof, other body parts or the like. In still other embodiments, the body portions may include animations on where, when or how to attach measurement devices.

The hub may also advantageously overlap parameter displays to provide additional visual information to the caregiver. Such overlapping may be user definable and configurable. The display may also incorporate analog-appearing icons or graphical indicia.

In the interest of clarity, not all features of an actual implementation are described in this specification. An artisan will of course be appreciate that in the development of any such actual implementation (as in any development project), numerous implementation-specific decisions must be made to achieve a developers' specific goals and subgoals, such as compliance with system- and business-related

constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking of device engineering for those of ordinary skill having the benefit of this disclosure.

To facilitate a complete understanding of the disclosure, the remainder of the detailed description describes the disclosure with reference to the drawings, wherein like reference numbers are referenced with like numerals throughout.

Embodiments of Monitoring Hub

FIG. **1**A illustrates a perspective view of an exemplary medical monitoring hub **100**, which may also be referred to herein as a monitor **100**, with an exemplary docked portable patient monitor **102** according to an embodiment of the disclosure. The hub **100** includes a display **104**, and a docking station **106**, which in an embodiment is configured to mechanically and electrically mate with the portable patient monitor **102**, each housed in a movable, mountable and portable housing **108**. The housing **108** includes a generally upright inclined shape configured to rest on a horizontal flat surface, although the housing **108** can be affixed in a wide variety of positions and mountings and comprise a wide variety of shapes and sizes.

In an embodiment, the display **104** may present a wide variety of measurement and/or treatment data in numerical, graphical, waveform, or other display indicia **110**. In an embodiment, the display **104** occupies much of a front face of the housing **108**, although an artisan will appreciate the display **104** may comprise a tablet or tabletop horizontal configuration, a laptop-like configuration or the like. Other embodiments may include communicating display information and data to a table computer, smartphone, television, or any display system recognizable to an artisan. The upright inclined configuration of FIG. **1**A presents display information to a caregiver in an easily viewable manner.

FIG. **1**B shows a perspective side view of an embodiment of the hub **100** including the housing **108**, the display **104**, and the docking station **106** without a portable monitor docked. Also shown is a connector for noninvasive blood pressure **113**.

In an embodiment, the housing **108** may also include pockets or indentations to hold additional medical devices, such as, for example, a blood pressure monitor or temperature sensor **112**, such as that shown in FIG. **1**C.

The monitor **102** may communicate with a variety of noninvasive and/or minimally invasive devices such as optical sensors with light emission and detection circuitry, acoustic sensors, devices that measure blood parameters from a finger prick, cuffs, ventilators, and the like. The monitor **102** may include its own display **114** presenting its own display indicia **116**, discussed below with reference to FIGS. **19**A-**19**J. The display indicia may advantageously change based on a docking state of the monitor **102**. When undocked, the display indicia may include parameter information and may alter orientation based on, for example, a gravity sensor or accelerometer.

In an embodiment, the docking station **106** of the hub **100** includes a mechanical latch **118**, or mechanically releasable catch to ensure that movement of the hub **100** doesn't mechanically detach the monitor **102** in a manner that could damage the same.

Although disclosed with reference to particular portable patient monitors **102**, an artisan will recognize from the disclosure herein a large number and wide variety of medical devices that may advantageously dock with the hub **100**. Moreover, the docking station **106** may advantageously electrically and not mechanically connect with the monitor **102**, and/or wirelessly communicate with the same.

FIG. **2** illustrates a simplified block diagram of an exemplary monitoring environment **200** including the hub **100** of FIG. **1**, according to an embodiment of the disclosure. As shown in FIG. **2**, the environment may include the portable patient monitor **102** communicating with one or more patient sensors **202**, such as, for example, oximetry optical sensors, acoustic sensors, blood pressure sensors, respiration sensors or the like. In an embodiment, additional sensors, such as, for example, a NIBP sensor or system **211** and a temperature sensor or sensor system **213** may communicate directly with the hub **100**. The sensors **202**, **211** and **213** when in use are typically in proximity to the patient being monitored if not actually attached to the patient at a measurement site.

As disclosed, the portable patient monitor **102** communicates with the hub **100**, in an embodiment, through the docking station **106** when docked and, in an embodiment, wirelessly when undocked, however, such undocked communication is not required. The hub **100** communicates with one or more multi-patient monitoring servers **204** or server systems, such as, for example, those disclosed with in U.S. Pat. Pub. Nos. 2011/0105854, 2011/0169644, and 2007/0180140. In general, the server **204** communicates with caregiver backend systems **206** such as EMR and/or ADT systems. The server **204** may advantageously obtain through push, pull or combination technologies patient information entered at patient admission, such as demographical information, billing information, and the like. The hub **100** accesses this information to seamlessly associate the monitored patient with the caregiver backend systems **206**. Communication between the server **204** and the monitoring hub **100** may be any recognizable to an artisan from the disclosure herein, including wireless, wired, over mobile or other computing networks, or the like.

FIG. **2** also shows the hub **100** communicating through its serial data ports **210** and channel data ports **212**. As disclosed in the forgoing, the serial data ports **210** may provide data from a wide variety of patient medical devices, including electronic patient bed systems **214**, infusion pump systems **216** including closed loop control systems, ventilator systems **218**, blood pressure or other vital sign measurement systems **220**, or the like. Similarly, the channel data ports **212** may provide data from a wide variety of patient medical devices, including any of the foregoing, and other medical devices. For example, the channel data ports **212** may receive data from depth of consciousness monitors **222**, such as those commercially available from SEDLine, brain or other organ oximeter devices **224**, noninvasive blood pressure or acoustic devices **226**, or the like. In an embodiment, channel device may include board-in-cable ("BIC") solutions where the processing algorithms and the signal processing devices that accomplish those algorithms are mounted to a board housed in a cable or cable connector, which in some embodiments has no additional display technologies. The BIC solution outputs its measured parameter data to the channel port **212** to be displayed on the display **104** of hub **100**. In an embodiment, the hub **100** may advantageously be entirely or partially formed as a BIC solution that communicates with other systems, such as, for example, tablets, smartphones, or other computing systems.

Although disclosed with reference to a single docking station **106**, the environment **200** may include stacked docking stations where a subsequent docking station mechanically and electrically docks to a first docking station

to change the form factor for a different portable patent monitor as discussed with reference to FIG. **5**. Such stacking may include more than 2 docking stations, may reduce or increase the form fact for mechanical compliance with mating mechanical structures on a portable device.

FIG. **3** illustrates a simplified exemplary hardware block diagram of the hub **100** of FIG. **1**, according to an embodiment of the disclosure. As shown in FIG. **3**, the housing **108** of the hub **100** positions and/or encompasses an instrument board **302**, the display **104**, memory **304**, and the various communication connections, including the serial ports **210**, the channel ports **212**, Ethernet ports **305**, nurse call port **306**, other communication ports **308** including standard USB or the like, and the docking station interface **310**. The instrument board **302** comprises one or more substrates including communication interconnects, wiring, ports and the like to enable the communications and functions described herein, including inter-board communications. A core board **312** includes the main parameter, signal, and other processor(s) and memory, a portable monitor board ("RIB") **314** includes patient electrical isolation for the monitor **102** and one or more processors, a channel board ("MID") **316** controls the communication with the channel ports **212** including optional patient electrical isolation and power supply **318**, and a radio board **320** includes components configured for wireless communications. Additionally, the instrument board **302** may advantageously include one or more processors and controllers, busses, all manner of communication connectivity and electronics, memory, memory readers including EPROM readers, and other electronics recognizable to an artisan from the disclosure herein. Each board comprises substrates for positioning and support, interconnect for communications, electronic components including controllers, logic devices, hardware/software combinations and the like to accomplish the tasks designated above and others.

An artisan will recognize from the disclosure herein that the instrument board **302** may comprise a large number of electronic components organized in a large number of ways. Using different boards such as those disclosed above advantageously provides organization and compartmentalization to the complex system.

Embodiments of Touch Screen Controls Including Certain Gestures

FIG. **4** illustrates a legend of finger control gestures **400** for use with a touchscreen display **104** according to an embodiment. The finger control gestures **400** include a touch **402**, a touch and hold **404**, a touch and move **406**, a flick **408**, a drag and drop **410**, and a pinch **412**. A touch **402** is a finger control gesture that executes the desired action once the user's finger is released from the screen. A touch and hold **404** is a finger control gesture that executes the desired action once the user has held his or her finger on the screen continuously for a predetermined duration (e.g., a few seconds), received a "hold completion" notification, and has released his or her finger from the screen. A touch and move **406** is a finger control gesture that manipulates and/or translates objects across the display **104** in the desired and permitted direction to a deliberate stopping point. To execute a touch and move finger control gesture **406**, the user touches an object, moves the object (left, right, up, down, diagonally, etc.), and releases the object. A flick **408** is a finger control gesture comprising contact of an object on the display **104** in conjunction with a quick finger movement in a particular direction, typically along a single vector. To execute a flick **408** finger control gesture the user touches an object on the display **104**, moves the object (typically, but not necessarily in a single direction) and releases the finger from the display **104** quickly, in a manner such that the contact point has a velocity throughout its path of motion. A drag and drop **410** is a finger control gesture by which the user moves an object to another location or to another object (e.g., a folder) and positions it there by releasing it. To execute a drag and drop **410** finger control gesture, the user touches, holds, drags and drops the object. A pinch **412** is a finger control gesture that expands or contracts the field of view on the display **104**. To execute a pinch **412** finger control gesture, the user touches the display **104** at two touch points using two fingers, for example, the thumb and index finger of a user's hand. Moving the touch points apart from each other zooms in on the field of view, enlarging it, while moving the touch points together zooms out on the field of view, contracting it.

In an embodiment the user interface includes multiple controls. For example, a toggle control enables a user to slide a knob to switch between toggle states. The toggle control also enables the user to press left or right of the toggle to quickly move the toggle left or right. If the toggle control is labeled, the user can press the label to quickly move the knob left or right.

The following paragraphs include a description of additional touch screen controls that can be used with the system of the present disclosure. The system can include any combination of the following controls and the present disclosure is not intended to be limited by the following descriptions of various controls.

In some embodiments, a spinner control enables the user to press a center (focused) tile to expand a spinner when the spinner is closed and to collapse a spinner when the spinner is opened. The spinner control enables the user to swipe up or down which, when the spinner is open, scrolls through spinner tiles. The spinner control enables the user to press an unfocused tile which then scrolls the tile into a center, focused position. And the spinner control enables the user to collapse an open spinner by pressing anywhere outside the spinner.

A slider control enables the user to move a knob by sliding the knob. The slider control also enables the user to quickly move the knob to a specific position by pressing anywhere along the slider path.

A slider spinner control combines the control capabilities of the spinner control and the slider control.

A button control enables a user to perform an action, as defined by the button description, by pressing the button.

An icon menu control enables the user to open a specified menu by pressing a tile. The icon menu control enables the user to scroll icons left or right by swiping left or right anywhere on the display. The icon menu control enables the user to quickly center a tile corresponding to an indicator icon by pressing an indicator button.

A window control enables the user to open a parameter or measurement window when no parameter or measurement alarm is present, by pressing the parameter or measurement. The window control enables the user to silence a parameter or measurement alarm when a parameter or measurement alarm is present, by pressing the parameter or measurement. The window control enables a parameter or measurement to be moved to a different location on the display **104** by using a drag and drop **410** finger control gesture.

A well control enables the user to open a parameter or measurement menu when no parameter or measurement alarm is present, by pressing the parameter or measurement. The well control enables the user to silence a parameter or

measurement alarm when a parameter or measurement alarm is present, by pressing the parameter or measurement.

A live waveform control enables the user to separate waveforms by swiping down. The live waveform control enables the user to combine waveforms by swiping up.

A trend line control enables the user to zoom in by pinching in, zoom out by pinching out, change a time range by panning, and open a parameter or measurement trend menu by pressing the y-axis.

An alarm silence icon control enables the user to silence all alarms by pressing the alarm silence icon.

An audio pause icon control enables the user to pause audio for a predetermined period of time, by pressing the audio pause icon.

Other status bar icon controls enable the user to open the relevant menu, by pressing the relevant status bar icon.

A back arrow control enables the user to exit a menu or abandon any changes made, by pressing a back arrow icon.

A confirm-or-cancel control enables the user to confirm changes to settings by pressing an OK button. The confirm-or-cancel control enables the user to cancel changes to settings by pressing a cancel button.

A home control enables the user to navigate to the main screen at any time by pressing a home button.

Embodiments of Configurable Replay Display

FIG. **5** illustrates an embodiment of a user interface **500** displayed on the display **104** of the hub **100**. In an embodiment the display **104** comprises a color, modular, touch-screen integral to the hub **100**. Positioned horizontally along the top of the display **104** is a top status line **501** that displays system status as well as that provides shortcuts to menu items or actions. In an embodiment the icons presented on the top status line **501** include alarm silence **501**A, audio pause **501**B, profiles **501**C, Bluetooth **501**D, Wi-Fi **501**E, Ethernet **501**F, connectivity gateway **501**G, portable patient monitor battery status **501**H, monitoring hub battery status **501**I, sounds **501**J, and current time **501**K.

The alarm silence icon **501**A displays alarm status and mutes all audible alarms for monitoring devices connected to the hub **100**. The audio pause icon **501**B displays audio pause status and temporarily silences an alarm event. The profiles icon **501**C provides access to a profiles screen; the example shown illustrates that the profile is set to "Adult" for an adult patient. The Bluetooth icon **501**D provides access to a Bluetooth screen. If this icon is visible on the status line **501**, then Bluetooth connectivity has been enabled. The Wi-Fi icon **501**E provides access to a Wi-Fi screen. If this icon is visible on the status line **501**, then Wi-Fi connectivity has been enabled. The icon itself also indicates the strength of the wireless signal. The Ethernet icon **501**F provides access to an Ethernet screen. If this icon is visible on the status line **501**, then Ethernet connectivity has been enabled.

The connectivity gateway icon **501**G provides access to a connectivity gateway screen. The example illustrated indicates that standalone devices are connected to three of the available four ports. The color of the icon matches the status colors of the connected standalone devices. The portable patient monitor battery status icon **501**H displays the charging status of the portable patient monitor **102** and provides access to a portable patient monitor battery screen. The example illustrates that the battery is currently charging. The monitoring hub battery status icon **501**I displays the charging status of the monitoring hub **100** and provides access to a monitoring hub battery screen. The example illustrates that the battery is currently charging. The sounds icon **501**J provides access to a sounds screen to adjust alarm and pulse tone volume. In an embodiment the sounds icon **501**J does not indicate the actual volume level of the alarm and the pulse tone. The current time icon **501**K displays the current time and provides access to a localization screen which contains settings related to local time, language and geography.

Positioned horizontally along the bottom of the display **104** is a bottom status line **502** that displays additional icons and information including a main menu icon, a gender icon, and a patient identifier that includes patient-specific information, such as, for example, the patient's name and room location. Although the disclosed embodiment employs status lines **501**, **502** oriented horizontally along the top and bottom of the display **104**, one skilled in the art would readily appreciate that information of the type presented in the top status line **501** and in the bottom status line **502** may be presented in numerous different formats, combinations and configurations, including without limitation, one or more status bars positioned vertically on the display **104**. Moreover a skilled artisan will appreciate that other useful information may be displayed in status bars **501**, **502**.

In an embodiment the user interface can create a window for every monitoring device connected to the hub **100**. Parameters or measurements can be expanded within a window to customize views. A central portion **504** of the display **104** presents patient measurement data, in this example, in two windows **506**, **530**. Illustratively, by way of non-limiting example, an upper window **506** presents patient data measured by an a noninvasive monitoring platform, such as the Rainbow® Pulse CO-Oximetry™ monitoring platform by Masimo Corporation of Irvine, Calif., which enables the assessment of multiple blood constituents and physiologic parameters including oxygen saturation (SpO_2) **508**, pulse rate (PR) **510**, respiration rate (RRp) **512**, fractional arterial oxygen saturation ($SpfO_2$) **514**, total hemoglobin (SpHb) **516**, plethysmograph variability index (PVI) **518**, methemoglobin (SpMet) **520**, carboxyhemoglobin (SpCO) **522**, perfusion index (PI) **524**, oxygen content (SpOC) **526**, or others. In the illustrated example, the lower window **530** of the display **104** presents patient data measured by a regional oximetry platform, such as the O_3™ regional oximetry module by Masimo Corporation of Irvine, Calif., which allows the continuous assessment of tissue oxygenation beneath one or more sensors placed on the patient's skin to help clinicians detect regional hypoxemia.

Advantageously, the display **104** is configurable to permit the user to adjust the manner by which the physiologic parameters are presented on the display **104**. In particular, physiologic measurements of greater interest or importance to the clinician may be displayed in larger format and may also be displayed in both numerical and graphical formats to convey the current measurement as well as the historical trend of measurements for a period of time, such as, for example, the preceding hour. In an embodiment the oxygen saturation **508**, pulse rate **510**, and respiration rate **512** measurements are displayed in such a manner, taking up a larger portion of the upper portion **506** of the display **104**, while the fractional arterial oxygen saturation **514**, total hemoglobin **516**, plethysmograph variability index **518**, methemoglobin **520**, carboxyhemoglobin **522**, perfusion index **524**, and oxygen content **526** measurements are displayed as numbers, taking up a smaller portion of the upper portion **506** of the display **104**.

In an embodiment the presentation of measurement information may be adjusted easily by using the finger control gestures **400**. For example, the touch and move **406** finger control gesture may be used to move an object on the display

104 representing a measurement from one location of the display 104 to another location of the display 104. Advantageously, when the object is moved, the display 104 automatically scales its presentation of information based upon the parameters that are active. For example, fewer parameters result in the presentation of larger digits, trend lines, and waveform cycles. In an embodiment the location to which an object is moved determines, at least in part, the manner by which that object will be presented on the display 104.

Attention is now directed to a plurality of analysis presentation views that may be presented on the disclosed monitoring hub 100. Advantageously, the disclosed monitoring hub 100 provides many analytical formats by which measured physiological parameters, as well as other data, can be displayed to the user. Size, format, color, and location on the display, among other things, can be easily set and modified by the clinician-user to readily customize the manner by which monitored physiological parameter data, as well as information derived therefrom, can be displayed.

FIG. 6A is an illustration of an exemplary display screen 600 showing various formats of analytical presentation views for illustrating received physiological parameter data, according to an embodiment of the disclosure. The exemplary display screen 600 includes heat map analytical presentation views 602, box-and-whisker analytical presentation views 604, an index analytical presentation view 606, distribution analytical presentation views 608, histogram analytical presentation views 610, and gauge-histogram analytical presentation views 612. The positions of each analytical presentation view may be adjusted and the format of each analytical presentation view may be substituted with other formats, advantageously resulting in a high degree of customization for the user. For example, the gauge-histogram presentation views 612 are situated vertically in a right side panel portion of the screen 600, but may instead be situated in any formation and in any position on the screen 600.

Heat Maps

A heat map 602 analytical presentation view provides a two-dimensional graphical representation of a relationship between two measured parameters over a specified period of time, using color to identify areas in the graph where the data is concentrated. For example, as illustrated in FIG. 6B, the heat map 602 presents the relationship between measured oxygen saturation (SpO2) and pulse rate (PR) at specific points in time. Illustratively, by way of non-limiting example, an area on the graph corresponding to the highest concentration of correlated values between measured oxygen saturation and pulse rate is colored in a first color (e.g., red). FIG. 6B shows the heat map centered around an SpO2 value of about 98% and a PR value of about 61 bpm. Moreover, FIG. 6B shows that as the concentration of correlated measurements decreases, the colors on the heat map change (e.g., from red to orange, then to yellow, then to green, and finally to blue) indicating progressively lower concentrations of correlated values between the two measured parameters.

Heat maps 602 advantageously provide a trend of multiple monitored values or physiological parameters at a mere glimpse. For example, FIG. 6B shows a caregiver that while the PR for the patient may be a little low, depending on age, fitness, activity level during monitoring, or the like, the patient was almost if not entirely fully saturated with oxygen. Thus, because the body appears to be oxygenated, additional PR may not be needed during the time period presented. Accordingly and advantageously, the heat map 602 delivers a visual summary of the data that enables the user to intuitively understand and analyze complex relationships between data sets.

Box-And-Whisker Plots

In descriptive statistics, a box plot or boxplot is a convenient way of graphically depicting groups of numerical data through their quartiles. Box plots may also have lines extending vertically from the boxes (whiskers) indicating variability outside the upper and lower quartiles, these are often called box-and-whisker plots or diagrams. The spacings between the different parts of the box indicate the degree of dispersion (spread) and skewness in the data, and show outliers.

As shown in FIG. 6C, a box-and-whisker plot analytical presentation view 604 visually presents the range of measurements received over a specified or pre-determined period of time, and the boundaries of the quartiles in which the data lies. Advantageously, the box-and-whisker view 604 readily presents to the user the degree of spread, or dispersion, of the measured data, as well as the skewness in the data, including outlier measurements. The whiskers 620 and 622 identify the low end and high end, respectively, of the range of measurements displayed.

By way of illustrative example, as depicted in FIG. 6C, the range of measured SpO2 data for a given patient may extend from 82% to 100%. An artisan will recognize other patient's may have many other ranges. The box 624 identifies the median line 626 of the measured SpO2 parameter data. Thus, half of the measured SpO2 data represented by the view 604 falls above the median line 626 and half of the measured SpO2 data falls below the median. The lower edge 628 and the upper edge 630 of the box 624 identify the medians of the lower and upper half of the measured SpO2 data, respectively. Thus, as illustrated in FIG. 6C, a first quartile of measured SpO2 data lies between the end point of the bottom whisker 620 and the bottom edge 628 of the box 624; a second quartile of measured SpO2 data lies between the bottom edge 628 of the box 624 and the median line 626; a third quartile of measured SpO2 data lies between the median line 626 and the top edge 630 of the box 624; and a fourth quartile of measured SpO2 data lies between the top edge 630 of the box 624 and the end point of the top whisker 622.

Again, box-and-whisper plots 604 advantageously provide a trend of a monitored value or physiological parameter at a mere glimpse. For example, FIG. 6C shows a caregiver that while SpO2 varied somewhat, at least half the time it was above about 94% and a quarter of the monitored window SpO2 was between about 94% and about 98%. While about half of the time, SpO2 was lower than perhaps desired.

Index Views

An index analytical presentation view 606, such as the continuous, noninvasive measurement of arterial hemoglobin concentration, which may also be referred to as a "total hemoglobin" (SpHb) index 606, exemplarily illustrated in FIG. 6D, presents a current measured state of a physiological parameter (SpHb, in this example) relative to ranges identified as acceptable, cautionary, and emergent. As illustrated in FIG. 6D, an indicator 632 shows a current measured parameter level relative to a vertical bar 634. The vertical bar 634 is shaded in different colors, such as, for example, green, yellow and red. The colors can be used to identify different regions or zones corresponding to, for example, acceptable, cautionary, and emergent values of the measured parameter. A threshold line 636 can be set to visually identify one zone from another. Illustratively, by way of non-limiting example,

the threshold line **636** can identify the boundary between the range of acceptable values and the range of cautionary values of the measured parameter. In an embodiment, the user can set the ranges and boundary conditions for such ranges. In other embodiments, the ranges and boundary conditions for a given physiological parameter are set to default values corresponding to generally clinically accepted values for such ranges. The units of the measured parameter can be presented in a well **638** at the bottom of the index analytical presentation view **606**. For example, as illustrated in FIG. **6**D, the units of the physiological parameter being measured (total hemoglobin, SpHb) are in grams per deciliter (g/dL) at a confidence interval (C.I.) of ninety percent. Advantageously, the index analytical display provides to the user an easily-interpreted presentation of the measured physiological parameter.

Distribution Views

A distribution analytical presentation view **608**, such as the SpO2 distribution display **608** illustrated in FIG. **6**E, presents a statistical distribution of a set of physiological parameter measurements over a specified or pre-defined period of time. The distribution analytical presentation view **608** provides the user a visual representation of the range of physiological parameter measurements collected as well as a statistical distribution associated with such measurements. Illustratively, by way of non-limiting example, the distribution analytical presentation view **608** shown in FIG. **6**E presents a distribution **640** of the oxygen saturation (SpO2) parameter measurements over a period of time. In the example depicted in FIG. **6**E, the distribution **640** is substantially normal (or Gaussian) with its mean (or expected value) **642** illustrated as well. A current measured value indicator **644** informs the user of the present state of the patient, and a standard deviation indicator **646** indicates the degree to which the measured data varies or disperses over the range of values. A well **648** toward the bottom of the distribution analytical display **608** provides numerical units of the measured physiological parameter, such as percentage for the oxygen saturation measurement.

Histogram Views

A histogram analytical presentation view **610**, as illustrated in FIG. **6**F, provides another graphical representation of a collection of measured physiological parameter data. A histogram represents an estimate of the statistical (or probability) distribution of a continuous variable, such as a continuously measured physiological parameter. Thus, rather than providing a statistical distribution (i.e., a probabilistic model) that best fits or corresponds to the measured data, the histogram reflects the actual measured data collected. To form a histogram, the entire range of values to be measured is divided into a series of often equally-spaced, often consecutive, often non-overlapping intervals, referred to as "bins." Each physiological parameter measurement value is then allocated to one of the bins. A bar is drawn for each bin, where the height of the bar corresponds to the number of discrete physiological parameter measurements that fall within that bin's particular range. In an embodiment, the width of each bar is constant, corresponding to the ranges of the equally-spaced intervals. The histogram may also be normalized to display the relative frequency or proportion of measurements that fall into each of the several bins. Advantageously, the histogram analytical presentation view **610** provides the user a visual representation of the actual frequencies of the observed physiological parameter measurements in certain ranges of values.

Analog Gages Including Histogram Views

A gauge-histogram analytical presentation view **612**, as illustrated in FIG. **6**G, provides a combination of analog, digital and histogram display indicia in one presentational format view. Advantageously, the gauge-histogram analytical presentation view **612** provides to the user a substantial amount of information related to the measured physiological parameter in an intuitive and visually accessible format. The gauge-histogram **612** includes an analog indicator forming, for example, a semi-circular arc **650**. Portions of the arc **650** can be differentiated by use of various colors or shading to indicate different regions of measured parameter values, such as, for example, acceptable, cautionary and emergent regions of the gauge. Illustratively, by way of non-limiting example, the acceptable range of values can be colored green, and can be located generally centrally within the arc **650**, while cautionary ranges of values can be colored yellow and located beyond the acceptable range of values, and emergent ranges of values can be colored red and located beyond the cautionary value ranges toward the two ends of the arc **650**. Of course, one skilled in the art will appreciate that many other colors and range formats may be used without departing from the scope of the present disclosure.

The gauge-histogram analytical presentation view **612** can include a dial marker **652** that moves about the arc **650** reflecting the current measured level of the monitored physiological parameter. Illustratively, by way of non-limiting example, as the measured physiological parameter level increases, the dial can move clockwise, and as the measured physiological parameter level decreases, the dial can move counter-clockwise, or vice versa. In this way, a user can quickly determine the patient's status by looking at the analog indicator. For example, if the dial marker **652** is in the center of the arc **650**, the observer can be assured that the current physiological parameter measurement falls within the acceptable range. If the dial marker **652** is skewed too far to the left or right, the observer can quickly assess the severity of the physiological parameter level and take appropriate action. In other embodiments, acceptable parameter measurements can be indicated when the dial marker **652** is to the right or left, etc.

In some embodiments, the dial marker **652** can be implemented as a dot, a dash, an arrow, or the like, and the arc **650** can be implemented as a circle, a spiral, a pyramid, or any other shape, as desired. Furthermore, the entire arc **650** can be illuminated or only portions of the arc **650** can be illuminated, based for example, on the current physiological parameter being measured. Additionally, the arc **650** can turn colors or be highlighted based on the current measured physiological parameter level. For example, as the dial marker **652** approaches a threshold level, the arc **650** and/or the dial marker **652** can turn from green, to yellow, to red, shine brighter, flash, be enlarged, move to the center of the display, sound an alarm, or the like.

Different physiological parameters can have different thresholds indicating abnormal conditions. For example, some physiological parameters may have upper and lower threshold levels, while other physiological parameters may only have an upper threshold or a lower threshold level. Accordingly, each gauge-histogram analytical presentation view **612** can be adjusted based on the particular physiological parameter being monitored. Illustratively, by way of non-limiting example, an SpO2 gauge-histogram presentation view **612** can have a lower threshold, which when met, activates an alarm, while a respiration rate gauge-histogram presentation view **612** can have both a lower and an upper threshold, and when either threshold is met, an alarm can be

activated. The thresholds for each physiological parameter can be based on typical, expected thresholds, or they can be set to user-specified threshold levels.

In certain embodiments, such as the embodiment illustrated in FIG. **6**G, the gauge-histogram analytical presentation view **612** includes a digital indicator **654**. The analog arc **650** and digital indicator **654** can be positioned in any number of formations relative to each other, such as side-by-side, above, below, transposed, etc. In the illustrated embodiment, the analog arc **650** is positioned above the digital indicator **654**. As described above, the analog arc **650** and dial marker **652** may include colored warning sections, indicating a current position on the graph. The digital information designates quantitative information from the graph. In FIG. **6**G, for example, the gauge-histogram analytical presentation view **612** displays pulse rate information. The arc **650** shows that from about 50 to about 140 beats per minute, the measured pulse rate physiological parameter is either in the acceptable range or beginning to enter the cautionary range, whereas in the regions outside those numbers, the arc **650** is colored to indicate an emergent or severe condition. Thus, as the dial marker **652** moves along the arc, **650**, a caregiver can readily see where in the ranges of acceptable, cautionary, and emergent pulse rate values the current measurement falls. The digital indicator **654** provides a numerical representation of the current measured value of the physiological parameter being displayed. The digital indicator **654** may indicate an actual measured value or a normalized value, and it can also be used to quickly asses the severity of a patient's condition.

As illustrated in FIG. **6**G, a histogram arc **656** is located above and surrounding the arc **650**, having multiple radially-extending lines that correspond to histogram bins (as described above with respect to FIG. **6**F) for the measured physiological parameter. The bins of the histogram arc **656** can be illuminated to reflect the distribution of measured parameter values in the manner described above with respect to the histogram analytical presentation view **610**. In the embodiment illustrated in FIG. **6**G, the bins are illuminated in colors corresponding to the ranges along the arc **650** in which they fall. Thus, the disclosed gauge-histogram analytical presentation view **612** provides analog and digital indicia of the current measured physiological parameter, correlated with range information indicative of the level of urgency required for the measured parameter, as well as a visual display of the actual distribution of the patient's parameter measurements over a period of time.

Advantageously, the hub **100** stores the measured data that it has presented on the display screen **600** over time. In certain embodiments, the data is stored in the memory **304** of the instrument board **302**. In certain embodiments, the stored externally and accessed by the monitoring hub **100** via a network connection, such as, for example, an Ethernet connection. In still other embodiments, the data is stored in both on-board memory **304** and external storage devices.

Drag and Drop

Referring back to FIG. **6**A, each of the foregoing display elements **6**B, **6**C, **6**D, **6**E, **6**F and **6**G can be dragged onto the screen and dropped to create a customized view to match a caregiver's preferences for a particular monitored patient. In an embodiment, a display element and its particular displayed parameters are shown as icons along a bottom horizontally scrollable menu. When a caregiver wishes to place, for example, a Perfusion Variability Index (PVI) distribution view on the screen, he or she could select the PVI distribution icon from the bottom well, scroll, and drag it to the screen to, for example, replace any existing display element. In another embodiment, a caregiver may select a display element and then select the parameter or parameters to be provided to the element.

Replay

FIG. **6**A also shows the display screen **600** provides a replay feature, which permits the clinician to review a historical record of the patient data collected and processed by the monitor **100**. A user may select a time frame **662** for a replay period. For example, a user may select between replaying a previous ten-minute period, a four-hour period, or an eight-hour period. Any amount of time may be a suitable replay period. In an embodiment, the screen **600** may provide a default time frame **662**, for example eight hours. After a replay period is selected or a default period is determined, a user may select a replay icon **660** to begin replay.

In certain embodiments, the stored data may be replayed on different monitor hubs or on different displays (such as, for example, a display connected to a multi-patient monitoring server **204**), to permit clinicians who are remote from the patient's care environment to access and review the monitored data.

During a replay period, stored data may be displayed on the screen **600** at different rates. For example, the replayed data can be displayed at the same rate of time in which the data was originally presented. Thus, replaying one hour of recorded data would take one hour to fully replay. Alternatively, the replayed data can be displayed in slow-motion (slower than real-time), or in a time-lapse (faster than real-time) formats. For example, to replay in slow-motion, the screen **600** may present each frame of data for a longer period of time than originally presented. Illustratively, by way of non-limiting example, slow-motion replay can be useful to review and analyze portions of the recorded physiological parameter data in which abrupt changes occur. Time-lapse replay permits the clinician to review a period of recorded data over a shorter period of time than the data was originally presented. In an embodiment, to replay in time-lapse mode, a screen **600** may accelerate a speed at which frames are displayed. In another embodiment, to replay in time-lapse mode, a screen **600** may display only a sampling of frames from a set of data. For example, a screen **600** may display every fifteenth frame so that data may be presented in a shorter time while still providing a useful illustration of the stored data. In an embodiment, the user can select the rate at which the time-lapse replay will progress. For example, by way of illustration, the user might choose to view one minute's worth of real-time data in one second or in ten seconds. This information may be particularly useful to a care provider who would like to quickly review a patient's physiological conditions from a previous time period when, for example, the care provider was not present to observe the data as it was originally presented.

In certain embodiments, multiple parameter displays presented on the screen **600** may synchronously replay stored data during a replay period, while other parameter displays may present live data. This allows the clinician to concurrently monitor the present condition of the patient and review (i.e., replay) past measurement data. Illustratively, by way of non-limiting example, a series of analytical displays in a center portion of the screen **600** may replay stored data, while a series of gauge-histogram analytical displays **612**, located in a side panel, may present live data. In another embodiment, every feature on the screen **600** may replay stored data during a replay period. FIG. **7** illustrates such an example, and the display **700** provides a message **702** indicating that the displayed data is being replayed. In yet

another embodiment, any single analytical display or combination of analytical displays on the screen **600** may present live data during a replay period. In some embodiments, individual analytical displays may have individual icons or indicators (not shown) associated with them to indicate whether the analytical presentation view is presenting live or stored and replayed data. In some embodiments, an individual display element may include both replayed and live data.

FIG. **8** is a flowchart illustrating a replay process **800** according to an embodiment of the present disclosure. At optional block **802**, a user configures the display **600** with the display elements a caregiver desires for the monitored patient. The drag and drop functionality allows the user to straightforwardly drag the display elements to the portion of the screen desired. In an embodiment, a default screen layout could be implemented. Alternatively or additionally, the screen may be set to the most recent replay configuration, a replay configuration matched to a known user, known caregiver, or the patient, or some or all of the foregoing.

In optional block **804**, the user sets a time period for replay. As discussed above, any amount of time may be a suitable time period. For example, a user may choose between a two-hour, four-hour, eight-hour, or ten-minute replay period. In an embodiment, a user may select a timeframe icon **662** to set the time period. In other embodiments, the user can scroll backward on a timeline (not shown) to select a starting point and ending point for the replay. In other embodiments, the user can input a start time and end time for the replay.

At optional block **806**, the user may select a replay interval which defines the rate at which the replay displays. In certain embodiments, the replay interval includes real-time, slow-motion, and time-lapse intervals. Illustratively, a replay interval may be indicative of the number of frames of stored data which are displayed when selecting a time-lapse mode of replay. For example, a user may choose to have every fifteenth frame or every tenth frame of recorded data to be displayed in order to shorten the time required to replay stored data. In other embodiments, the user may be presented a timeline the width of the optionally selected time period and the user may pinch the timeline bigger or smaller to automatically adjust the interval.

At block **808**, time is set to the start of the time period. At block **810**, measurement data is accessed. In an embodiment, a processor accesses only the data used in the active display elements; in other embodiments, all the data associated with a particular time is accessed. In an embodiment, the processor synchronizes data to the display time even though such data may not be from the same measurement device. In other embodiments, synchronization data may be stored along with the original measurement data for use when accessed during the replay process **800**.

At block **812**, the data is displayed to the user through the configured display elements. At optional block **814**, a user may interrupt replay to pause, speed up or slow down the replay, zoom in or out on a time period, switch to another time period, end replay, change display elements, or otherwise manipulate the data being replayed. In optional block **816**, such interrupts are handled and appropriate action is taken, such as, for example, restarting replay with new configuration or time parameters.

At block **818**, the process **800** determines if playback has reached the end of the selected playback time period. If so, the process **800** ends; if not, the display rate is added to the current display time and the process **800** returns to block **810** to access additional data.

Advantageously, process **800** allows a caregiver to straightforwardly monitor a wide variety of measurements and combinations of measurements for a particular time period. For example, the caregiver may see during replay a heat map **602** fluctuate in color and/or position, pulse or otherwise show how the body of the patient is oxygenated and what pulse rate it is using for such oxygenation. Likewise, box-and-whisker plots **604** may have portions that grow, shrink, and move in rhythm with, for example, the heat map **602**. Distributions **608** may change and histograms along with their analog gages may provide indications of how the body is reacting over a course of pre-selected time.

As discussed above, a user may run a replay process by selecting a replay icon **660**. Once the replay process is complete, a user may choose whether to repeat the process, at block **808**. If the user chooses to repeat the process, the process **800** will again run at step **806**. If the user chooses not to repeat the process, the process will end at block **810**.

Thus, a patient monitoring hub that serves as the center of patient monitoring and treatment activities for a given patient is disclosed. Embodiments of the patient monitoring hub include a large visual display that dynamically provides information to a caregiver about a wide variety of physiological measurements or otherwise-determined parameters. Advantageously, the display can be customized by the clinician-user to present the desired physiological parameters (and other relevant information) in the formats and at the locations on the display that the clinician desires. Numerous analytical presentation views are provided to present the monitored physiological parameters (and other information) in visual formats that provide timely, clinically-relevant, and actionable information to the care provider. Additionally, the disclosed monitoring hub allows for replay of all or portions of the monitored data in a synchronized manner. The embodiments disclosed herein are presented by way of examples only and not to limit the scope of the claims that follow. One of ordinary skill in the art will appreciate from the disclosure herein that many variations and modifications can be realized without departing from the scope of the present disclosure.

The term "and/or" herein has its broadest least limiting meaning which is the disclosure includes A alone, B alone, both A and B together, or A or B alternatively, but does not require both A and B or require one of A or one of B. As used herein, the phrase "at least one of" A, B, "and" C should be construed to mean a logical A or B or C, using a non-exclusive logical or.

The term "plethysmograph" includes it ordinary broad meaning known in the art which includes data responsive to changes in volume within an organ or whole body (usually resulting from fluctuations in the amount of blood or air it contains).

The following description is merely illustrative in nature and is in no way intended to limit the disclosure, its application, or uses. For purposes of clarity, the same reference numbers will be used in the drawings to identify similar elements. It should be understood that steps within a method may be executed in different order without altering the principles of the present disclosure.

As used herein, the term module may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC); an electronic circuit; a combinational logic circuit; a field programmable gate array (FPGA); a processor (shared, dedicated, or group) that executes code; other suitable components that provide the described functionality; or a combination of some or all of the above, such as in

a system-on-chip. The term module may include memory (shared, dedicated, or group) that stores code executed by the processor.

The term code, as used above, may include software, firmware, and/or microcode, and may refer to programs, routines, functions, classes, and/or objects. The term shared, as used above, means that some or all code from multiple modules may be executed using a single (shared) processor. In addition, some or all code from multiple modules may be stored by a single (shared) memory. The term group, as used above, means that some or all code from a single module may be executed using a group of processors. In addition, some or all code from a single module may be stored using a group of memories.

The apparatuses and methods described herein may be implemented by one or more computer programs executed by one or more processors. The computer programs include processor-executable instructions that are stored on a non-transitory tangible computer readable medium. The computer programs may also include stored data. Non-limiting examples of the non-transitory tangible computer readable medium are nonvolatile memory, magnetic storage, and optical storage. Although the foregoing invention has been described in terms of certain preferred embodiments, other embodiments will be apparent to those of ordinary skill in the art from the disclosure herein. Additionally, other combinations, omissions, substitutions and modifications will be apparent to the skilled artisan in view of the disclosure herein. Accordingly, the present invention is not intended to be limited by the reaction of the preferred embodiments, but is to be defined by reference to claims.

Additionally, all publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

What is claimed is:

1. A portable device configured to display physiological parameters of a user, the device comprising:

an electronic processor configured to be in wireless communication with one or more physiological sensors worn on a body part of the user, wherein the one or more physiological sensors comprise a pulse oximetry sensor, the electronic processor further configured to receive values of at least some of the physiological parameters measured by the one or more physiological sensors; and

a touchscreen display, wherein, responsive to a first input from the user, the touchscreen display is configured to display received values of the physiological parameters by visually presenting a range of historical oxygen saturation values, received over a first time interval in a vertical bar, the first input comprising the user's selection of a timeframe icon and the first time interval being based on the user's selection of the timeframe icon, wherein a height of the vertical bar indicates a degree of spread of data measured by the pulse oximetry sensor, a top and bottom of the vertical bar indicating respectively a high end and a low end of the historical oxygen saturation values, and wherein in response to a second input from the user, the touchscreen display is configured to automatically adjust the vertical bar to visually present a different range of historical oxygen saturation values received over a second time interval different from the first time interval.

2. The device of claim **1**, wherein the electronic processor is further configured to be in wireless communication with one or more medical devices to receive data of other ones of the physiological parameters measured by the one or more medical devices.

3. The device of claim **2**, wherein the one or more medical devices are made by at least two different manufacturers.

4. The device of claim **1**, wherein the touchscreen display is further configured to display the received values of the physiological parameters in one or more of numerical, graphical, waveform, or trend lines.

5. The device of claim **1**, wherein the touchscreen display is further configured to display respiratory rate values by visually presenting a range of the respiratory rate values received over a specified or pre-determined period of time in a vertical bar.

6. The device of claim **1**, wherein the oxygen saturation values are continuously measured oxygen saturation values.

7. The device of claim **1**, wherein the electronic processor is configured to add encryption to the received physiological parameter measurements.

8. The device of claim **1**, wherein the electronic processor is configured to communicates with a caregiver's data management system to advantageously associate the received values of the physiological parameters with the user on the data management system.

9. The device of claim **8**, wherein the electronic processor is configured to pass the received values of the physiological parameter to the data management system without the caregiver associating each physiological sensor with the patient.

10. A portable device configured to display physiological parameters of a user, the device comprising:

an electronic processor configured to be in wireless communication with one or more physiological sensors worn on a body part of the user, wherein the one or more physiological sensors comprise a pulse oximetry sensor, the electronic processor further configured to receive values of at least some of the physiological parameters measured by the one or more physiological sensors; and

a touchscreen display, wherein, responsive to a first input from the user, the touchscreen display is configured to display the received values of the physiological parameters by visually presenting a range of historical values of one of the physiological parameters received over a first time interval in a vertical bar, the first input comprising the user's selection of a timeframe icon and the first time interval being based on the user's selection of the timeframe icon, wherein a height of the vertical bar indicates a degree of spread of measured data of the one of the physiological parameters, a top and bottom of the vertical bar indicating respectively a high end and a low end of the historical values of the one of the physiological parameters received, and wherein in response to a second input from the user, the touchscreen display is configured to automatically adjust the vertical bar to visually present a different range of historical values of the one of the physiological parameters received over a second time interval different from the first time interval.

11. The device of claim **10**, wherein the electronic processor is further configured to be in wireless communication with one or more medical devices to receive data of other ones of the physiological parameters measured by the one or more medical devices.

12. The device of claim 11, wherein the one or more medical devices are made by at least two different manufacturers.

13. The device of claim 10, wherein the touchscreen display is further configured to display the received values of the physiological parameters in one or more of numerical, graphical, waveform, or trend lines.

14. The device of claim 10, wherein the one of the physiological parameters is heart rate or oxygen saturation.

15. The device of claim 10, wherein the one of the physiological parameters respiratory rate.

16. The device of claim 10, wherein the electronic processor is configured to add encryption to the received physiological parameter measurements.

17. The device of claim 10, wherein the electronic processor is configured to communicates with a caregiver's data management system to advantageously associate the received values of the physiological parameters with the user on the data management system.

18. The device of claim 17, wherein the electronic processor is configured to pass the received values of the physiological parameters to the data management system without the caregiver associating each physiological sensor with the patient.

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